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SOURCE INVENTORY AND EMISSION FACTOR ANALYSIS.

VOLUME I

PEDCo-Environmental Specialists, Incorporated

September 1974

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September 1974

SOURCE INVENTORY AND EMISSION FACTOR ANALYSIS, VOLUME I

U.S. ENVIRONMENTAL PROTECTION AGENCY
Office of Air and Waste Management
Office of Air Quality Planning and Standards
Research Triangle Park, North Carolina 27711

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This report describes a Source Inventory and Emission Factor Analysis (SIEFA), a program designed to determine the precision of emission inventories. Through application of the SIEFA program, users of the data generated in an emission inventory will have at hand not only the values derived from emission calculations but a definition of their quality; that is, a statement of the statistical precision of each value and the precision of the overall emission inventory. Throughout this report these words have the following meaning:

Precision - A measure of variability, due to unknown factors which affect a measurement made on similar elements from a population. This variability is assumed to be random.

Accuracy - The degree to which data are biased.

The precision values generated herein are not actually "true" precision, but rather the best estimate of precision that could be obtained.

PRICES SUBJECT TO CHANGE

17. KEY WORDS AND DOCUMENT ANALYSIS

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Source Inventory NEDS Emission Factor Precision Accuracy Area Source Point Source		

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by

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Prepared for

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Office of Air and Waste Management
Office of Air Qualtiy Planning and Standards
Research Triangle Park, North Carolina 27711

September 1974

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1.0 INTRODUCTION

Air pollutant emission inventories have been made for every major metropolitan region in the United States pursuant to submittal of State Implementation Plans under the Clean Air Act. Additional emission inventories are undertaken to implement the control efforts of various state, regional, and local agencies and to provide a base for research and development of air pollution control technology.

This report describes a Source Inventory and Emission Factor Analysis (SIEFA), a program designed to determine the precision of emission inventories. Through application of the SIEFA program, users of the data generated in an emission inventory will have at hand not only the values derived from emission calculations but a definition of their quality; that is, a statement of the statistical precision of each value and the precision of the overall emission inventory. Throughout this report these words have the following meaning:

Precision -	A measure of variability, due to unknown factors which affect a measurement made on similar elements from a population. This variability is assumed to be random.
Accuracy -	The degree to which data are biased.

Cont

The precision values generated herein are not actually "true" precision, but rather the best estimate of precision that could be obtained.

The SIEFA program is based on and is compatible with the National Emissions Data System (NEDS) of the U.S. Environmental Protection Agency (EPA). As the national repository of air pollution-related data, NEDS provides the format for virtually all substantive emissions inventories performed by agencies, groups, and individuals nationwide. NEDS computer programs and coding forms, together with the EPA "Compilation of Air Pollutant Emission Factors"(AP-42), are the basic tools of an emission inventory. SIEFA is able to accomodate changes to the program, such as a change in an emission factor or an additional Source Classification Code (SCC). For specific instructions regarding changes, refer to the SIEFA Users Manual.

In formulating the SIEFA program, PEDCo has calculated or estimated a precision value for each individual emission factor used in the NEDS. In this report we show how each precision value was derived and document the basis for each assumption or estimate involved. Where an emissions value is based on several parameters, such as control device efficiency, process thruput, or sulfur/ash content of fuels, a statistical or engineering analysis is applied to determine the precision of each parameter. By statistical scrutiny of each component of input, the SIEFA program thus indicates the level of confidence that can be assigned to an emission inventory. The output from SIEFA presents precision in terms of the standard deviation (S) of the estimated emissions. For computational purposes it is necessary to use the variance (i.e., Var (E) = S^2). The variance of an emission value is calculated by the equation:

$$\mathrm{Var}(E) = E^2 \left[P_1^{\,2} + P_2^{\,2} + \cdots + P_n^{\,2} \right]$$

where E = emissions in tons/yr.

P_1, P_2, etc. = Precision of the various factors used to calculate E.

Precision is defined as follows:

$$P_i = \frac{S_i}{\bar{X}_i}$$

where

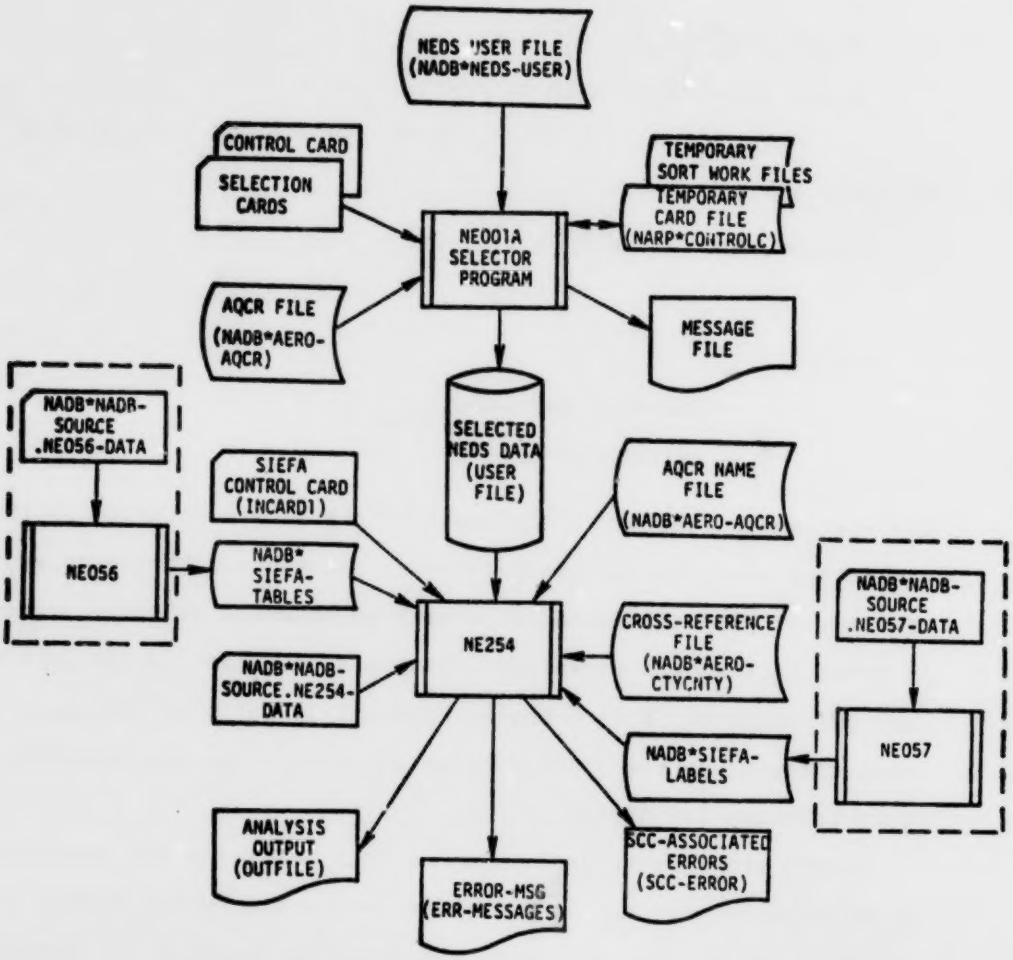
S_i = standard deviation

$\bar{X}_i$ = arithmetic mean

The variance of the total emissions in any source category is the sum of the variances of the individual emissions. The measure of error or precision associated with an emission value is stated in terms of standard deviation. Standard deviation is the square root of variance. A flow chart (Figure 1.1) outlines the basic steps followed by the SIEFA program in calculating the precision of an emission inventory.

SIEFA provides an indication of both precision and accuracy of emission values, but in different ways. The output format gives precision values quantitatively, as standard deviations. Similar quantitative values for accuracy cannot be determined, however, since any known methods of finding a 'true' emissions value are

SIEFA SYSTEMS FLOWCHART


NEDS USER FILE (NADB*NEDS-USER)
CONTROL CARD
SELECTION CARDS
TEMPORARY SORT WORK FILES
TEMPORARY CARD FILE (NARP*CONTROLC)
NE001A SELECTOR PROGRAM
AQCR FILE (NADB*AERO-AQCR)
MESSAGE FILE
NADB*NADB-SOURCE .NE056-DATA
NE056
SELECTED NEDS DATA (USER FILE)
SIEFA CONTROL CARD (INCARD1)
AQCR NAME FILE (NADB*AERO-AQCR)
NADB* SIEFA-TABLES
NE254
NADB*NADB-SOURCE .NE057-DATA
CROSS-REFERENCE FILE (NADB*AERO-CTYCNTY)
NADB*NADB-SOURCE.NE254-DATA
NADB*SIEFA-LABELS
NE057
ANALYSIS OUTPUT (OUTFILE)
ERROR-MSG (ERR-MESSAGES)
SCC-ASSOCIATED ERRORS (SCC-ERROR)

NE056 is run only when point source tables are changed; e.g., a new SCC code(s) is added.

NE057 is run only if changes are made to the output labels.

Figure 1.1 Flow chart of the SIEFA program.

either impractical or are themselves subject to error, or both. Efforts in the direction of finding 'true' emissions values, such as auditing of company records or supervision of source testing, are beyond the scope of the SIEFA program.

With respect to the accuracy of emission factors, it is widely recognized that some are based on very meager data and in fact could not be representative of all sources in a category to which they are applied. In efforts to maintain the best possible array of working data, EPA updates the AP-42 emission factors whenever new information obtained in source testing or by some other reliable method provides a basis for revision. In addition, SIEFA increases the accuracy of emissions reporting by providing approximated values where elements of data are missing. Since the SIEFA output clearly shows how many values are thus approximated, it provides the user with an index to the relative accuracy of the values. Methods of determining and applying the approximated values are discussed in Section 4.

This report is presented in three major parts: Section 2 develops precision values for data on emissions from point sources; Section 3 deals with emissions from area sources; and Section 4 presents a system for computerizing the quality analysis of emissions data.

Part one
Part two
Part three

2.0 PRECISION OF POINT SOURCE EMISSIONS DATA

In the EPA procedure for preparing emissions inventories, emissions from point sources are calculated from data recorded on the NEDS point source coding form (Figure 2.1). Precision of the emission estimates is determined by the precision of these input data. For point sources the factors used to calculate emissions are the emission factor, control device efficiency, thruput, and sulfur or ash content of fuels. Code numbers that indicate the method used to estimate the emission factor are entered, by pollutant, on card 4, columns 66 through 70, of the point source form. Values for control efficiency are entered on card 3, columns 53 through 67; for thruput (annual operating rate), on card 6, columns 26 through 32; and for sulfur and ash content, on card 6, columns 40 through 45.

In the following sections we analyze the methods by which these values are derived and develop a precision value to characterize each entry. These precision values then are entered into the SIEFA program for use in evaluating the precision of source inventories and emission data to meet the needs of the requestor.

2.1 PRECISION OF EMISSION FACTORS

Card 4 of the NEDS point source form indicates the method used in estimating emission factors. Codes are provided for

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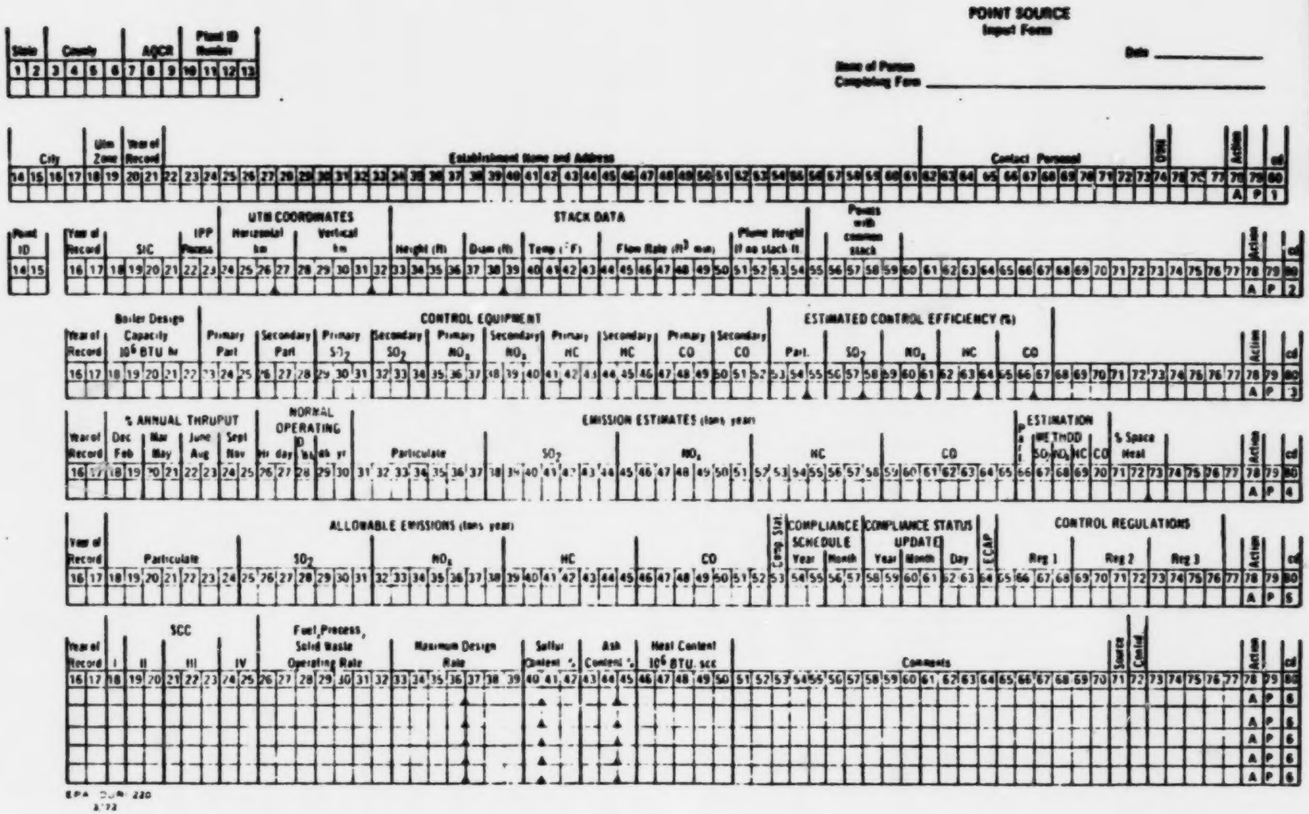

POINT SOURCE
Input Form

Name of Person Completing Form ______________

Date ______________

State		County				AQCR			Plant ID Number			
1	2	3	4	5	6	7	8	9	10	11	12	13

City	Utm Zone	Year of Record	Establishment Name and Address	Contact Personnel	OMB		Action		cd
14 15 16 17	18 19	20 21	22 23 24 25 26 27 28 29 30 31 32 33 34 35 36 37 38 39 40 41 42 43 44 45 46 47 48 49 50 51 52 53 54 55 56 57 58 59 60 61	62 63 64 65 66 67 68 69 70 71 72 73	74	75 76 77	78	79	80
							A	P	1

Point ID	Year of Record	SIC	IPP Process	UTM COORDINATES Horizontal km	UTM COORDINATES Vertical km	STACK DATA Height (ft)	STACK DATA Diam (ft)	STACK DATA Temp (°F)	STACK DATA Flow Rate (ft³/min)	STACK DATA Plume Height if no stack ft		Points with common stack		Action		cd
14 15	16 17	18 19 20 21	22 23	24 25 26 27	28 29 30 31 32	33 34 35 36	37 38 39	40 41 42 43	44 45 46 47 48 49 50	51 52 53 54	55	56 57 58 59	60 61 62 63 64 65 66 67 68 69 70 71 72 73 74 75 76 77	78	79	80
														A	P	2

Year of Record	Boiler Design Capacity 10^6 BTU/hr	CONTROL EQUIPMENT Primary Part	Secondary Part	Primary SO_2	Secondary SO_2	Primary NO_x	Secondary NO_x	Primary HC	Secondary HC	Primary CO	Secondary CO	ESTIMATED CONTROL EFFICIENCY (%) Part.	SO_2	NO_x	HC	CO		Action		cd
16 17	18 19 20 21 22	23 24 25	26 27 28	29 30 31	32 33 34	35 36 37	38 39 40	41 42 43	44 45 46	47 48 49	50 51 52	53 54 55	56 57 58	59 60 61	62 63 64	65 66 67	68 69 70 71 72 73 74 75 76 77	78	79	80
																		A	P	3

Year of Record	% ANNUAL THRUPUT Dec Feb	Mar May	June Aug	Sept Nov	NORMAL OPERATING hr/day	D wk	wk/yr	EMISSION ESTIMATES (tons/year) Particulate	SO_2	NO_x	HC	CO		ESTIMATION METHOD SO_2	NO_x	HC	CO	% Space Heat		Action		cd
16 17	18 19	20 21	22 23	24 25	26 27	28	29 30	31 32 33 34 35 36 37	38 39 40 41 42 43 44	45 46 47 48 49 50 51	52 53 54 55 56 57 58	59 60 61 62 63 64 65	66	67	68	69	70	71 72 73	74 75 76 77	78	79	80
																				A	P	4

Year of Record	ALLOWABLE EMISSIONS (tons/year) Particulate	SO_2	NO_x	HC	CO	Comp Stat	COMPLIANCE SCHEDULE Year	Month	COMPLIANCE STATUS UPDATE Year	Month	Day	ECAP	CONTROL REGULATIONS Reg 1	Reg 2	Reg 3		Action		cd
16 17	18 19 20 21 22 23 24	25 26 27 28 29 30 31	32 33 34 35 36 37 38	39 40 41 42 43 44 45	46 47 48 49 50 51 52	53	54 55	56 57	58 59	60 61	62 63	64	65 66 67 68	69 70 71 72	73 74 75 76	77	78	79	80
																	A	P	5

Year of Record	SCC I	II	III	IV	Fuel, Process, Solid Waste Operating Rate	Maximum Design Rate	Sulfur Content %	Ash Content %	Heat Content 10^6 BTU/scc	Comments	Source	Contd		Action		cd
16 17	18	19 20	21 22 23	24 25	26 27 28 29 30 31 32	33 34 35 36 37 38 39	40 41 42	43 44 45	46 47 48 49 50	51 52 53 54 55 56 57 58 59 60 61 62 63 64 65 66 67 68 69 70	71	72	73 74 75 76 77	78	79	80
														A	P	6
														A	P	6
														A	P	6
														A	P	6
														A	P	6

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Figure 2.1. Point source coding form.

five methods of estimation:

Code	Method
1	Source-test data or other emission measurements.
2	Material balance based on engineering knowledge and expertise.
3	Emission factors from EPA's Compilation of Air Pollutant Emission Factors, AP-42.
4	Guess.
5	Special emission factor that differs from the official EPA factor.

All five estimation methods are considered as providing emission factors. Source test data and material balances are given in pounds per hour (lb/hr) or pounds per ton (lb/ton); these rates are essentially emission factors. Methods 3 and 5 entail use of values that are emission factors by definition. Values determined by guess, Method 4, are often based on emission factors determined for similar processes.

Precision values for emission factors determined by each of these methods are calculated in the following sections. The results provide a precision value for each emission factor by SCC; values are given in Tables G-1 through G-5 of Appendix G.

2.1.1 Precision of Emission Factors Determined by Method 1

In effect, the number obtained in a source test is an emission factor for that specific source. PEDCo therefore studied the source test data on file with EPA Emissions Measurements Branch to determine the precision of these data. This was done by calculating the standard deviation of each test series for various processes and pollutants. These calculations indicated that precision $\left(\frac{\sigma \bar{x}}{\bar{x}}\right)$ of the values obtained in source tests appears to depend on the pollutant.

We therefore selected at random 20 test series for each pollutant and calculated an average precision for each pollutant. Data obtained from the Emissions Measurements Branch were supplemented by test data from PEDCo files to complete a 20-test series for each pollutant. Results of the calculations are shown below.

Pollutant	Average precision of test data
Particulate	0.196
SO_2	0.177
NO_x	0.134
HC	0.203
CO	0.321

These precision values were entered into the SIEFA program. Calculations of these values are shown in Appendix D.

2.1.2 Precision of Emission Factors Determined by Method 2

In Method 2 emissions are calculated by a material balance. A material balance can be made for some processes that emit particulate, SO_2, or HC. A material balance cannot be made for any process emitting NO_x or CO. Material balances were classified as involving either a chemical process (i.e. oxidation of sulfur contained in fuel) or a product loss (i.e. determined by amount of catalyst purchased for makeup for FCC units). The precision values assigned were based on the following criteria:

Basis of material balance	AP-42 EF available	Basis of precision estimate
Chemical process	Yes	Same as AP-42
Chemical process	No	Engineering analysis
Product loss	Yes	Size of total emission estimate
Product loss	No	

2.1.2.1 Material Balance for SO_2 Emissions - The pollutant for which the majority of sources are amendable to material balance is SO_2. All of the SO_2 material balances are for oxidation of sulfur contained in fuel. For some sources an AP-42 emission factor was also available; in these cases the material balance was assigned the same precision value that is assigned to the emission factor, since the AP-42 emission factor incorporates the percent conversion from sulfur to SO_2. For the processes that are not assigned an AP-42 emission factor, an engineering analysis was performed to determine the precision of the material balances, as described in the following paragraphs.

Lignite boilers - Lignite contains sulfur in the form of pyrite and organic sulfur compounds, such as mercaptors. Pyrite sulfur content ranges from 30 to 80 percent. Organic sulfides are easily oxidized, whereas the pyrites are more difficult to oxidize. The high moisture content (30 to 60%) of some sulfur compounds also hinders oxidation. Some of the sulfur is converted to calcium sulfate, but most is oxidized to SO_2 or SO_3. Sodium oxide content of the lignite also has a profound effect on SO_x emissions. Low-sodium lignite emits almost all

(90% or greater) of the sulfur as SO_x, whereas high-sodium lignite emits only half the sulfur as SO_x. It is, therefore, very difficult to generalize a percentage conversion of sulfur in lignite to sulfur oxide. Under good combustion conditions (i.e. the lignite is pulverized), yields of 90 to 98 percent SO_x are expected; under poor conditions (the lignite is moist, has high sodium content, occurs in large lumps), the SO_x yields can be as low as 50 percent. Most lignite boilers incorporate a pulverization system and/or a moisture-reducing process. Conversion is estimated to be around 90 percent, with a possible range of 50 to 98 percent. Assuming at least five observations:

$$\sigma' = \frac{\max - \min}{d_2}$$

$$d_2 = 2.33$$

$$\sigma' = \frac{98 - 50}{2.33} = 20.6\%$$

$$\sigma_x = \frac{\sigma'}{\sqrt{n}} = \frac{20.6}{2.236} = 9.2\%$$

$$\text{Precision of conversion estimate} = \frac{\pm 9.2\%}{90\%} = \pm 0.102$$

The sulfur content of lignite may range between 0.3 and 2.3 percent by weight. ASTM Designation: D271-48[1] specifies the precision of determination of sulfur content to be within the following limits:

$\% S < 2.0$ error = 0.1

$\% S \geq 2.0$ error = 0.2

Therefore the precisions are:

$$0 \leq \% S < 2.0 \qquad p = \frac{0.1}{\% S}$$

$$2.0 \leq \% S \qquad p = \frac{0.2}{\% S}$$

Process gas boilers - Several types of processes produce a gas with sufficient heating value to be utilized in a boiler. Process gases include refinery gas, coke oven gas, etc. Most of the sulfur in these gases appears as H_2S, with some thiols present also. The compounds oxidize readily and should show approximately 98 percent conversion to SO_x compounds. Assuming that the majority of process gas boilers operate under good combustion conditions, the standard error should be no more than ± 5 absolute percent. Thus, the precision of the conversion value will be $5/98 = \pm 0.051$.

The sulfur content of process gas may vary from 0 to 300 grains per 100 cubic feet. ASTM Designation: D1072-56 specifies an absolute precision of ± 0.1 grain per 100 cubic feet for determining the sulfur content of manufactured gases. Assuming an average molecular weight of the gas to be 30, an error of 0.1 grain per 100 cubic feet is equivalent to $\pm 1.7 \times 10^{-4}$ percent of sulfur by weight. Therefore, the precision of the sulfur content values equals $\pm \frac{1.7 \times 10^{-4}}{\% S}$.

Coke boilers - Little of the sulfur present in coking coals is removed through the coke oven gas. The remaining sulfur is usually of pyritic form and averages 1 percent by weight. In the combustion of coke, high temperatures are maintained and around 90 percent conversion of sulfur to SO_x compounds is expected. Based on six observations cited in Reference 3, a precision may be calculated.

$$\sigma' = \frac{R}{d^2}$$

$$R = \max - \min = 100 - 77$$

$$d_2 = 2.53$$

$$\sigma' = \pm 9.1$$

$$\sigma_x = \frac{\sigma'}{\sqrt{6}} = \frac{9.1}{2.449} = \pm 3.7$$

$$\text{Precision} = \pm \frac{3.7}{90} = 0.041$$

ASTM Designation: D271-48[1] also specifies the precision of determination of the sulfur content of coke as ± 0.05 absolute percent. The precision is then $\pm \frac{0.05}{\%\ S}$.

Boilers fueled by solid waste and coal - Some boilers are fueled by refuse mixed with coal. The sulfur content of the coal is easily determined, but that of the refuse depends on the type of refuse burned. If the refuse is garbage, the sulfur content is negligible[4] and the sulfur content of the coal determines SO_x emissions. Assume that such is the case. For most types of coal boilers, the mean conversion is 95 percent. On the basis of data for boilers burning wet, pulverized fuel (from Reference 3) and the method used in calculations for coke boilers, the precision is ± 0.118.

ASTM Designation: D271-48[1] specifies the following permissible errors:

Sulfur Content,%	Permissible Error,%
< 2.0	0.1
≥ 2.0	0.2

Sulfur content of United States coals range from 0.5 percent to 4.9 percent. Since solid waste/coal boilers are usually employed in power plants that burn coals having relatively high sulfur content, the precision is:

$0 \leq \% S \leq 2.0$	$0.1/\% S$
$2.0 \leq \% S$	$0.2/\% S$

Open burning of jet fuel - Open burning is not as efficient as combustion in a jet engine. Expected conversion is less, probably in the range of 70 to 90 percent.

$$\sigma' = \frac{90-70}{1.13} = 17.6$$

$$\sigma_x = \frac{17.6}{\sqrt{2}} = 12.5$$

$$\text{Precision} = \frac{12.5}{80} = \pm 0.156$$

The sulfur content would be as precise for engine testing. The precision equals $\frac{0.03}{\% S}$ for $0 \leq \% S < 0.5$.

Flare stacks - Analysis of determinations by material balance of emissions from flares indicated a high conversion from sulfur to SO_2. The maximum percent sulfur content that can be entered on the NEDS point source form is 9.99 percent. The sulfur content of flow to many petroleum flares, however, is much higher than this value. Therefore, sulfur contents above 9.99 percent remain unreported on the NEDS forms (for purposes of computer calculations). The ASME Power Test Codes do not give a precision value for determination of sulfur in refinery gas. Since both the flow to the flare and the sulfur content vary greatly during the year, sulfur content of the flare gas as reported by the refinery is not regarded as very precise. Because a material balance cannot be calculated from data on the NEDS form, it is assumed that the precision of a material balance for SO_2 emissions from flares is equal to the precision of the least precise emission factor in that category.

The precisions assigned to material balances for coal boilers that are not given an AP-42 emission factor are determined by Method 4 (guess), since the precision of a guess is equal to the precision of the least precise emission factor in a particular category. The precision assigned to material balances for processes designated by NEDS as "other/not classified" are also the precisions of a guess.

2.1.2.2 Material Balance for Particulate Emissions- Particulate emissions could be determined by material balance for three processes: sand handling operations in iron production, and FCC or TCC catalytic cracker operations.

The material balance for sand handling operations involves the amount of make-up sand purchased to replace sand lost to the atmosphere. The amount of make-up sand purchased, however, is not normally reported to a high degree of precision. Precisions would be in the range of 50 ± 10, 25 ± 5, or 10 ± 2, giving a precision value of ± 0.200.

Material balances for particulate emissions from the catalytic crackers were based on the amount of catalyst purchased to make up losses of catalyst to the atmosphere. Some of the TCC catalyst losses, however, are due to discarding pellets that have been broken up but were not expelled to the atmosphere. Further, the thruput value entered on the NEDS forms is in thousands of barrels of fresh feed through the crackers, a value not related to the amount of catalyst purchased or lost. Therefore, since the thruput data in the computer is not compatible with catalyst make-up, the precision assigned to the material balance method is the same as that assigned to the AP-42 emission factor.

2.1.2.3 Material Balance for HC Emissions - The processes for which HC emissions could be determined by material balance are dry cleaning, degreasing, surface coating, and printing. These processes all involve product losses, and precision is related to the thruput.

HC emissions from dry cleaning are considered equal to the amount of solvent purchased, since the solvent is reused, and all losses of solvent are considered due to evaporation. On the NEDS form, however, emissions from dry cleaning are reported as tons of clothes cleaned; since these units do not reflect the amount of solvent purchased, the precision assigned to the material balance method is the same as the precision of the emission factor.

Degreasing emissions also equal the amount of solvent purchased, since the solvent is reused and the only losses are due to evaporation. The units on the NEDS form for degreasing are tons of solvent used, which can be interpreted as tons of solvent purchased each year. Since the amount purchased equals the evaporation losses, precision of the material balance is based entirely on thruput, for which precision values are calculated separately (Section 2.3). The precision of the material balance estimate for degreasing, therefore, is zero.

Material balance calculations of HC emissions from surface coating include the HC content of the coating material. The precisions of the AP-42 emission factors are essentially the precision of determining the solvent content of the coating materials. Therefore, the precision of material balance estimates for surface coating is equal to the precision of the AP-42 emission factor. Since AP-42 gives no emission factor for surface coating operations designated as "other/not classified", values for these operations are assigned the precision value of the least precise emission factor in the category.

Emissions from printing can be calculated by material balance because, as in degreasing, the solvent is recovered and reused and the amount of solvent purchased is used to make up the amount lost by evaporation. The NEDS units for printing emissions are tons of solvent so the amount of solvent purchased is entered on the form. The only imprecision is in the thruput, and the material balance method itself is considered precise. Therefore, the precision of the material balance estimate for printing operations is zero.

2.1.3 Precision of Emission Factors Determined by Method 3

Method 3 entails use of the emission factors given in EPA's "Compilation of Air Pollutant Emission Factors," Publication No. AP-42. (Research Triangle Park, N.C., 2nd Edition, April 1973). These emission factors are referred to as AP-42 factors.

Because of the large number of emission factors used in NEDS, priorities were assigned to those processes and pollutants that account for the major portion of total emissions. These priority groupings, developed by EPA, are shown in Table 2.1. Because it is not practical for the system to consider only priority process/pollutants in determining precision of an overall emission inventory, an average precision for AP-42 emission factors was calculated by standard statistical methods.

The statistical analyses were based on the AP-42 factors and the observed values, as reported in references given in AP-42, on which the factors are based. Analysis of the references showed that the observed values are not reported consistently. Three basic inconsistencies appear: (1) the observed value was a controlled emission, i.e., a value measured or estimated downstream from an air pollutant control device, (2) the observed value was reported as negligible, and (3) the observed value was reported as a range. To account for these inconsistencies, the following rules were developed:

- A value reported for a controlled emission is not used in the statistical analysis, since efficiency of the control device is unknown.

Table 2.1 PRIORITY PROCESS-POLLUTANT EMISSIONS

SHOWN RELATIVE TO TOTAL EMISSIONS FOR A TYPICAL YEAR

1. Particulates - total 17,132,000 tons/year

Pulverized, dry bottom, boiler (bituminous coal)	3,130,000
Cement manufacturing (wet and dry)	2,000,000
Industrial bituminous coal combustion (area)	1,350,000
Stone quarrying	950,000
Petroleum industry - process heater	800,000
Pulverized, wet bottom, boiler (bituminous coal)	650,000
Petroleum industry - fluidized crackers	600,000
Spreader stokers (bituminous coal)	550,000
Lime manufacturing	500,000
Asphalt concrete	460,000
Brick manufacturing	350,000
Ferroalloy - 90% FESI	235,000
Iron production - sintering	225,000
Ceramic clay	133,000
Iron production - blast furnace - agglomerate charge	126,000
	12,000,000

2. SO_x - total 29,300,000 tons/year

Pulverized, dry bottom, boiler (bituminous coal)	11,000,000
Copper smelter	2,900,000
Pulverized, wet bottom, boiler (bituminous coal)	2,200,000
Cyclone boiler (bituminous coal)	2,100,000
Fluidized crackers	1,320,000
Industrial coal combustion - bituminous coal - area sources	900,000
Spreader stoker (bituminous coal)	900,000
Residual oil	760,000
	21,000,000

3. NO_x - total 21,300,000 tons/year

Light vehicles (gasoline)	4,940,000
Petroleum industry - process heater	2,800,000
Pulverized, dry bottom, boiler (bituminous coal)	2,300,000
Natural gas (point)	1,480,000
Heavy vehicles (diesel)	1,140,000
Cyclone boiler (bituminous coal)	900,000
Pulverized, dry bottom, boiler (bituminous coal)	760,000
Heavy vehicles (gasoline)	700,000
Pulverized, wet bottom, boiler (bituminous coal)	650,000
Residual oil	532,000
Industrial natural gas combustion - area sources	223,000
Industrial coal combustion (bituminous) - area sources	176,000
	16,500,000

Table 2.1 (Continued). PRIORITY PROCESS-POLLUTANT EMISSIONS SHOWN RELATIVE TO TOTAL EMISSIONS FOR A TYPICAL YEAR

4. HC - 231,000,000 tons/year

Light vehicles (gasoline)	10,520,000
Carbon black (channel process)	1,480,000
Heavy vehicles (gasoline)	1,400,000
Solvent evaporation loss (miscellaneous)	1,380,000
Gas handling evaporation	914,000
Off-highway (gasoline)	823,000
Petroleum storage - floating roof	426,000
Surface coating - paint	420,000
	17,400,000

5. CO - 99,600,000 tons/year

Light vehicles (gasoline)	57,000,000
Heavy vehicles (gasoline)	5,750,000
Off-highway (gasoline)	4,510,000
Petroleum industry - fluid crackers	4,400,000
Carbon black (channel process)	4,300,000
Mov. bed. cat. crackers	2,530,000
Iron production (blast furnace/sintering)	2,130,000
Gray iron cupola	1,300,000
Carbon black - furnace process oil	521,000
Carbon black - furnace with gas/oil	480,000
	83,000,000

- A value reported as negligible is not used in the statistical analysis since it cannot be equated to a value of zero.
- A value reported as a range is considered as one observation whose value is the mean. If no other observations are reported in the references, the range is considered as two observations (maximum and minimum) in calculating a standard deviation (S) and coefficient of variation (C.V.).

In calculating the standard deviation of an emission factor, one must consider that the emission factor (EF) is not always the mean ($\bar{X}$) of the observed values. While we are not certain which data were used in developing an emission factor, it is a reasonable assumption that the coefficient of variation of the emission factor ($C.V._f$) is approximately equal to the coefficient of variation of the mean of the observations ($C.V._{\bar{X}}$). Thus:

$$C.V._{\bar{X}} = \frac{S_{\bar{X}}}{\bar{X}} = C.V._f = \frac{S_f}{EF} \qquad \text{(eq. 1)}$$

Upon calculating $S_{\bar{X}}$ then, S_f is found thus:

$$S_f = EF \times C.V._{\bar{X}} \qquad \text{(eq. 2)}$$

The precision of the emission factor depends not only on the standard deviation but also on the number of observations upon which the standard deviation is based. In other words, the confidence level for an emission factor derived from 15 observations is greater than that for a number derived from 2 observations. The statistical expression for the variability of the emission factor is $\frac{S}{\sqrt{n}}$, which is also known as the standard error of the mean, or the standard error of the emission factor (E). Since emission factors are expressed in various units, E must be converted to a dimensionless number. This number is known as the precision (P) where:

$$P = \frac{E}{EF} \qquad \text{(eq. 3)}$$

In some instances the SCC used in the NEDS includes more than one emission point, and emission values are the summation of emissions calculated from more than one emission factor. The standard deviation of the combined emission factor (EF_{sum}) is expressed as follows:

$$S_{sum} = \left(S_1^{\,2} + S_2^{\,2}\right)^{1/2} \qquad \text{(eq. 4)}$$

Where S_1 and S_2 are the standard deviations of each of the separate emission factors.

Likewise, where the emission factor is expressed as a range, an average standard deviation (S_{avg}) must be estimated thus:

$$S_{avg} = 1/2 \left(S_1^{\,2} + S_2^{\,2}\right)^{1/2} \qquad \text{(eq. 5)}$$

2.1.3.1 Standard Deviation of AP-42 Emission Factors Based on Two or More Observations - The methods used for calculating the standard deviation ($S_{\bar{X}}$) of the mean of emission factor observations is determined by the number of observations upon which the emission factor is based. For this purpose, the AP-42 factors are divided into two groups: those based on 2 to 12 observations and those based on more than 12 observations.

For 2 to 12 observations, the standard deviation is determined from the following equation:

$$S_{\bar{X}} = (x_{max} - x_{min})/d_2 \qquad \text{(eq. 6)}$$

where x_{max} is the highest observation

x_{min} is the lowest observation

d_2 is an adjustment factor used to estimate the standard deviation of a universe and is given for each corresponding n for n = 1 to n = 12.[5]

For more than 12 observations, a normal distribution equation is used:

$$S_{\bar{X}} = \sqrt{\frac{n\Sigma x^2 - (\Sigma x)^2}{n\ (n - 1)}} \qquad \text{(eq. 7)}$$

2.1.3.2 Standard Deviation of AP-42 Emission Factors Based on Less Than Two Observations - Some AP-42 factors are based on only one observation; for others, not even one observation could be found in the references. In these cases the standard deviation can best be estimated by assuming that C.V.'s for all AP-42 factors tend to average, and that the emission factor is the mean of any observations that could have been made. The standard deviation then may be expressed thus:

$$S_f = C.V._{avg} \times EF \qquad \text{(eq. 8)}$$

$C.V._{avg}$ is determined by taking the average C.V. of all AP-42 factors based on five or more observations. These values are shown in Tables 2.2 through 2.6. Before the C.V.'s were averaged, selected values were discarded as nonrepresentative. For example, if the mean of the observations was outside the EF + 50% range, the resultant C.V. was not used. Also we rejected

Table 2.2 CALCULATION OF COEFFICIENT OF VARIATION FOR ALL PARTICULATE EMISSION FACTORS BASED ON FIVE OR MORE OBSERVATIONS

Process	Emission factor, EF	No. of obs., n	Arith. mean, $\bar{x}$	St'd. dev. of obs., s_x	Coeff. of variation, $C.V._x$	Comments regarding rejected values
Brick-periodic coal kiln	1.6A	10	1.29A	2.31A	1.79	C.V. out-of-line with other C.V.'s
Cement kiln - dry	245	10	244	159	0.652	
Cement kiln - wet	228	13	223	164	0.735	
Textile glass furnace-regen.	16.4	5	17.2	7.63	0.444	
Textile glass furnace-recup.	27.8	13	37.3	6.38	0.171	
Textile curing ovens	1.2	21	4.75	12.6	2.65	$\bar{x}$ outside EF ± 50% - range
Wool glass furnace-recup.	28.3	8	30.5	19.6	0.643	
Wool curing oven	3.5	6	13.7	13.2	0.964	$\bar{x}$ outside EF ± 50% - range
Wool cooling	1.3	5	1.31	1.59	1.21	
Gray iron cupola	17	6	13.6	8.78	0.646	
Steel foundry electric arc	13	29	11.7	8.21	0.702	
H_2SO_4 mfg. recovered sulfur	0.35-0.8	7	0.700	0.463	0.661	
H_2SO_4 mfg. dark virgin sulfur	0.32-6.3	7	2.57	2.18	0.848	
Inciner. mun. multi chamber	30	178	23.7	13.3	0.561	
Inciner. mun. multi chamber w/settling chamber	14	9	3.99	3.81	0.955	$\bar{x}$ outside EF + 50% - range
Incineration ind. & comm. multi chamber	7	13	3.85	2.01	0.522	
Incin. flue fed single chamber	30	12	37.1	21.3	0.574	
Incin. flue fed modified	6	6	5.08	2.09	0.411	
Open burning municipal refuse	16	6	30.1	17.8	0.591	$\bar{x}$ outside EF ± 50% - range
Agriculture field burning	17	14	15.3	3.91	0.256	

Table 2.2 (continued). CALCULATION OF COEFFICIENT OF VARIATION FOR ALL PARTICULATE EMISSION FACTORS BASED ON FIVE OR MORE OBSERVATIONS

Process	Emission factor, EF	No. of obs., n	Arith. mean, $\bar{x}$	St'd. dev. of obs., $s_{\bar{x}}$	Coeff. of variation, $C.V._{\bar{x}}$	Comments regarding rejected values
Asphaltic concrete	45	5	38.8	10.7	0.276	
(Bit.) pulv. general boiler	16A	18	15.4A	5.03A	0.327	
(Bit.) pulv. wet boiler	13A	89	13.1A	3.61A	0.276	
(Bit.) pulv. dry boiler	17A	34	18.3A	5.23A	0.286	
(Bit.) pulv. cyclone boiler	2A	44	2.72A	1.20A	0.441	
Spreader stoker	13A	17	12.4A	6.77A	0.546	
Indus. & comm. distillate oil	15	74	14.5	9.73	0.671	
Nat. gas dom. & comm. heating	19	5	18.3	11.4	0.623	
LPG dom. & commercial butane	1.9	5	1.70	1.06	0.624	
LPG dom. & commercial propane	1.8		1.58	0.985	0.623	

Average = 0.549

Table 2.3 CALCULATION OF COEFFICIENT OF VARIATION FOR ALL SULFUR DIOXIDE EMISSION FACTORS

BASED ON FIVE OR MORE OBSERVATIONS

Process	Emission factor, EF	No. of obs., n	Arith. mean, $\bar{x}$	Std. dev. of obs., $s_{\bar{x}}$	Coeff. of variation, C.V.$_{\bar{x}}$	Comments regarding rejected values
Brick-periodic coal kiln	12S	10	11.7S	3.41S	0.292	
Copper roasters	60	8	605	377	0.623	$\bar{x}$ outside EF + 50% - range
Copper smelters	320	16	249	209	0.839	C.V. out of line with other C.V.'s
Copper converters	870	16	688	237	0.344	
H_2SO_4 mfg. 96% conversion	55	8	68.1	10.1	0.148	
H_2SO_4 mfg. 97% conversion	40	5	43.1	10.8	0.251	
H_2SO_4 mfg. 98% conversion	27	8	31.1	4.65	0.150	
(Bit.) pulv. wet boiler	38S	7	38.3S	12.0S	0.313	
(Bit.) pulv. dry boiler	38S	8	38.3S	11.4S	0.298	
Power plant residual oil	157S	78	131S	31.1S	0.237	

Average =0.254

Table 2.4 CALCULATION OF COEFFICIENT OF VARIATION FOR ALL NITROGEN OXIDE EMISSION FACTORS BASED ON FIVE OR MORE OBSERVATIONS

Process	Emission factor, EF	No. of obs., n	Arith. mean, $\bar{x}$	St'd. dev. of obs., $s_{\bar{x}}$	Coeff. of variation, C.V.$_{\bar{x}}$	Comments regarding rejected values
Brick-periodic oil kiln	1.7	5	5.88	4.72	0.804	$\bar{x}$ outside EF ± 50% - range
Brick-periodic coal kiln	1.4	11	4.23	1.99	0.471	$\bar{x}$ outside EF ± 50% - range
Textile glass furnace-regen.	9.2	5	9.48	7.04	0.743	
Textile glass furnace-recup.	29.2	13	59.6	46.6	0.782	$\bar{x}$ outside EF ± 50% - range
Textile curing oven	2.6	18	3.01	10.0	3.22	C.V. - out of line with other C.V.'s
Wool glass furnace-recup.	1.7	8	2.26	2.04	0.903	
Wool curing oven	1.1	6	0.975	1.40	1.44	
Uncontrolled weak HNO_3 prod.	50-55	13	52.5	29.2	0.556	
Controlled weak HNO_3 prod.	2-7	6	11.6	11.3	0.974	
Incin. municipal multi chamber	3	21	2.99	1.11	0.371	
Incin. ind. & comm. multi cmbr	3	6	2.20	0.909	0.450	
Open burning municipal refuse	6	6	10.5	9.88	0.941	
Landscape refuse	2	5	2.10	1.50	0.714	
(Bit.) pulv. general boiler	18	11	14.7	3.33	0.227	
(Bit.) pulv. dry boiler	18	12	16.4	3.25	0.198	
I[illegible]. & comm. resid. oil	40-80	591	72.1	5.07	0.070	C.V. out of line with other C.V.'s
Domestic oil	12	589	71.8	8.96	0.125	$\bar{x}$ outside EF ± 50% - range
Power plant resid. oil	105	477	100	109	1.09	
Ind. & comm. distillate oil	40-80	591	67.6	183	0.027	C.V. out of line with other C.V.'s
Power plant natural gas	600	28	409	104	0.254	

Table 2.4 (continued). CALCULATION OF COEFFICIENT OF VARIATION FOR ALL NITROGEN OXIDE EMISSION FACTORS BASED ON FIVE OR MORE OBSERVATIONS

Process	Emission factor, EF	No. of obs., n	Arith. mean, $\bar{x}$	St'd. dev. of obs., $s_{\bar{x}}$	Coeff. of variation, C.V.$_{\bar{x}}$	Comments regarding rejected values
Dom. & commercial natural gas	80-120	15	102	74.1	0.726	
LPG dom. & commercial butane	8-12	5	14.6	11.7	0.801	
LPG dom. & commercial propane	7-11	5	13.5	10.9	0.807	

Average = 0.700

Table 2.5 CALCULATION OF COEFFICIENT OF VARIATION FOR ALL HYDROCARBON EMISSION FACTORS BASED ON FIVE OR MORE OBSERVATIONS

Process	Emission factor, EF	No. of obs., n	Arith. mean, $\bar{x}$	St'd. dev. of obs., $s_{\bar{x}}$	Coeff. of variation, C.V.$_{\bar{x}}$	Comments regarding rejected values
Brick-periodic coal kiln	0.9	10	0.305	0.091	0.298	$\bar{x}$ outside EF + 50% - range
Pet. storage floating roof	(140) 40-210	58	280	351	1.25	
Incineration industrial and commercial multi chamber	3	9	1.73	1.29	0.746	
Agriculture field burning	20	14	12.0	5.02	0.418	
(Bit.) pulv. general boiler	0.3	7	0.27	0.342	1.27	
Ind. & comm. residual oil	3	73	14.4	9.40	0.653	$\bar{x}$ outside EF $\pm$ 50% - range
Dom. & commercial natural gas	8	5	25.8	35.7	1.38	$\bar{x}$ outside EF $\pm$ 50% - range

Average = 0.921

Table 2.6 CALCULATION OF COEFFICIENT OF VARIATION FOR ALL CARBON MONOXIDE EMISSION FACTORS

BASED ON FIVE OR MORE OBSERVATIONS

Process	Emission factor, EF	No. of obs., n	Arith. mean, $\bar{x}$	St'd. dev. of obs., $s_{\bar{x}}$	Coeff. of variation, C.V.$_{\bar{x}}$	Comments regarding rejected values
Brick-periodic coal kiln	3.2	10	0.604	0.180	0.298	$\bar{x}$ outside EF ± 50% - range
Textile glass furnace-recup.	0.9	13	2.04	1.46	0.716	$\bar{x}$ outside EF + 50% - range
Textile curing oven	1.5	20	2.51	3.72	1.48	
Wool glass furnace-recup.	0.25	6	0.273	0.159	0.582	
Wool curing oven	1.7	5	1.74	0.984	0.566	
Steel production B.O.F.	139	8	163	48.4	0.297	
Agriculture field burning	100	14	98.2	25.0	0.255	
(Bit.) pulv. wet boiler	1	7	0.700	1.00	1.43	
Indus. & commercial resid. oil	4	22	3.93	1.20	0.305	
Power plant oil	3	9	2.46	2.78	1.07	
Indus. & commercial dist. oil	4	22	3.58	1.41	0.394	
Power plant natural gas	17	5	54.4	60.1	1.10	$\bar{x}$ outside EF ± 50% - range

Average = 0.709

those C.V.'s that were completely out of line with other C.V.'s for the same pollutant. Average C.V.'s by pollutant are as follows:

Pollutant	$C.V._{avg}$
Particulate	0.549
SO_x	0.254
NO_x	0.700
HC	0.921
CO	0.709

2.1.3.3 Calculation of Precision of Each AP-42 Emission Factor - Having determined the standard deviation, and knowing the number of observations upon which the AP-42 factor is based, we calculated a precision value for each priority emission factor by use of eq. 3. These precision values are shown in Tables 2.7 through 2.11.

Precision values for nonpriority emission factors were not calculated as a part of this study. In order to estimate precision of an overall emission inventory, then, we calculated and applied the average precision of all priority emission factors. These calculations are shown in Table 2.12 through 2.16. The average precisions of AP-42 emission factors as shown below by pollutant:

Pollutant	Average Precision
Particulate	0.211
SO_x	0.146
NO_x	0.172
HC	0.237
CO	0.357

Table 2.7 PRECISION OF PARTICULATE EMISSION FACTORS FOR PRIORITY PROCESSES

SCC				Emission factor, EF	No. of obs., n	Arith. mean, $\bar{x}$	Std. dev. of obs., s_m	Coeff. of variation, C. V.	Std. dev. of emission factor, S_f EF x C.V.	Std. dev. of emission factor, E $\frac{S_f}{\sqrt{n}}$	Precision, P $\frac{E}{EF}$
1	01	002	01	13A	89	13.1A	3.61A	0.276	3.59A	0.381A	0.029
1	01	002	02	17A	34	18.3A	5.23A	0.286	4.86A	0.833A	0.049
1	01	002	04	13A	17	12.4A	6.77A	0.546	7.10A	1.72 A	0.132
1	01	002	06	13A	89	13.1A	3.61A	0.276	3.59A	0.381A	0.029
1	01	002	07	17A	34	18.3A	5.23A	0.286	4.86A	0.833A	0.049
1	01	002	08	13A	17	12.4A	6.77A	0.546	7.10A	1.72 A	0.132
1	01	002	10	2A	1	a		0.549	1.10A	1.10 A	0.549
1	01	002	12	17A	34	18.3A	5.23A	0.286	4.86A	0.833A	0.049
1	02	002	01	13A	89	13.1A	3.61A	0.276	3.59A	0.381A	0.029
1	02	002	02	17A	34	18.3A	5.23A	0.286	4.86A	0.833A	0.049
1	02	002	04	13A	17	12.4A	6.77A	0.546	7.10A	1.72 A	0.132
1	02	002	07	13A	89	13.1A	3.61A	0.276	3.59A	0.381A	0.029
1	02	002	08	17A	34	18.3A	5.23A	0.286	4.86A	0.833A	0.049
1	02	002	09	13A	17	12.4A	6.77A	0.546	7.10A	1.72 A	0.132
1	02	002	12	17A	34	18.3A	5.23A	0.286	4.86A	0.833A	0.049
1	02	002	13	13A	17	12.4A	6.77A	0.546	7.10A	1.72 A	0.132
1	03	002	05	13A	89	13.1A	3.61A	0.276	3.59A	0.381A	0.029
1	03	002	06	17A	34	18.3A	5.23A	0.286	4.86A	0.833A	0.049
1	03	002	09	13A	17	12.4A	6.77A	0.546	7.10A	1.72 A	0.132
1	03	002	13	2A	1	a		0.549	1.10A	1.10 A	0.549
3	03	006	03	565	0	b		0.549	310	310	0.549
3	03	008	02	40	1	a		0.549	22.0	22.0	0.549
3	03	008	03	42	1	a		0.549	23.1	23.1	0.549
3	05	002	01	45	5	38.8	10.7	0.276	12.4	5.55	0.123
3	05	002	02	45	5	38.8	10.7	0.276	12.4	5.55	0.123

a) Where n is 1 or 0, average C.V., is used.
b) No reference available, emission factor is treated as one observation.
c) No observation found in references, emission factor is treated as one observation.

Table 2.7(Continued) PRECISION OF PARTICULATE EMISSION FACTORS FOR PRIORITY PROCESSES

SCC				Emission factor, EF	No. of obs., n	Arith. mean, $\bar{x}$	Std. dev. of obs., s_m	Coeff. of variation, C.V.	Std. dev. of emission factor, S_f EF x C.V.	Std. dev. of emission factor, E $\frac{S_f}{\sqrt{n}}$	Precision, P $\frac{E}{EF}$
3	05	003	01	96	0	c		0.549	52.7	52.7	0.549
3	05	003	02	96	0	c		0.549	52.7	52.7	0.549
3	05	003	03	34	0	c		0.549	18.7	18.7	0.549
3	05	003	04	0.07	3	0.07	0.0278	0.397	0.0278	0.0161	0.230
3	05	003	05	0.07	6	0.89	0.447	0.502	0.0351	0.0143	0.204
3	05	003	06	1.30	14	1.70	2.11	1.24	1.61	0.331	0.255
3	05	006	01	46	10	45.8	29.8	0.651	29.9	9.46	0.206
3	05	006	02	18	1	a		0.549	9.88	9.88	0.549
3	05	006	03	245	10	244	159	0.652	160	50.6	0.207
3	05	006	04	245	10	244	159	0.652	160	50.6	0.207
3	05	006	05	245	10	244	159	0.651	160	50.6	0.207
3	05	007	01	42.8	12	41.8	34.1	0.816	34.9	10.1	0.236
3	05	007	02	6	0	c		0.549	3.29	3.29	0.549
3	05	007	03	228	12	223	182	0.816	186	53.7	0.236
3	05	007	04	228	12	223	182	0.816	186	53.7	0.236
3	05	007	05	228	12	223	182	0.816	186	53.7	0.236
3	05	008	01	70	2	17.1	0.442	0.0258	1.81	1.28	0.018
3	05	008	02	76	0	c		0.549	41.7	41.7	0.549
3	05	008	03	34	0	c		0.549	18.7	18.7	0.549
3	05	016	01	31	0	c		0.549	17.0	17.0	0.549
3	05	016	02	2	0	c		0.549	1.10	1.10	0.549
3	05	016	03	8	1	a		0.549	4.39	4.39	0.549
3	05	016	04	200	4	134	70.1	0.523	105	52.5	0.263
3	05	020	01	0.5	1	a		0.549	0.275	0.275	0.549
3	05	020	02	1.5	1	a		0.549	0.824	0.824	0.549

a) Where n is 1 or 0, average C.V., is used.
b) No reference available, emission factor is treated as one observation.
c) No observation found in references, emission factor is treated as one observation.

Table 2.7(Continued) PRECISION OF PARTICULATE EMISSION FACTORS FOR PRIORITY PROCESSES

SCC				Emission factor, EF	No. of obs., n	Arith. mean, $\bar{x}$	Std. dev. of obs., s_m	Coeff. of variation, C.V.	Std. dev. of emission factor, S_f EF x C.V.	Std. dev. of emission factor, E $\frac{S_f}{\sqrt{n}}$	Precision, P = $\frac{E}{EF}$
3	05	020	03	6	1	a		0.549	3.29	3.29	0.549
3	05	020	04	5	1	a		0.549	2.75	2.75	0.549
3	05	020	05	6	1	a		0.549	3.29	3.29	0.549
3	05	020	06	2	0	c		0.549	1.10	1.10	0.549
3	05	020	07	10	0	c		0.549	5.49	5.49	0.549
3	06	001	01	840	1	a		0.549	461	461	0.549
3	06	001	02	0.2	1	a		0.549	0.110	0.110	0.549
3	06	001	03	20	1	a		0.549	11.0	11.0	0.549
3	06	001	04	200	1	a		0.549	110	110	0.549
3	06	002	01	242	2	166	185	1.11	269	190	0.785

a) Where n is 1 or 0, average C.V., is used.
b) No reference available, emission factor is treated as one observation.
c) No observation found in references, emission factor is treated as one observation.

Table 2.8 PRECISION OF SULFUR DIOXIDE EMISSION FACTORS FOR PRIORITY PROCESSES

SCC				Emission factor, EF	No. of obs., n	Arith. mean, $\bar{x}$	St d. dev. of obs., s_m	Coeff. of variation, C. V.	St d. dev. of emission factor, S_f EF x C.V.	St d. dev. of emission factor, E $\frac{S_f}{\sqrt{n}}$	Precision, P $\frac{E}{EF}$
1	01	002	01	38S	7	38.3S	12.0 S	0.313	11.9 S	4.50S	0.118
			02	38S	8	38.3S	11.4 S	0.298	11.3 S	4.00S	0.105
			03	38S	4	36.9S	3.30S	0.0894	3.40S	1.70S	0.045
			04	38S	1	a		0.254	9.65S	9.65S	0.254
			06	38S	7	38.3S	12.0 S	0.313	11.9 S	4.50S	0.118
			07	38S	8	38.3S	11.4 S	0.298	11.3 S	4.00S	0.105
			08	38S	1	a		0.254	9.65S	9.65S	0.254
			10	38S	1	a		0.254	9.65S	9.65S	0.254
			12	38S	8	38.3S	11.4 S	0.298	11.3 S	4.00S	0.105
1	01	004	01	157S	78	131 S	31.1 S	0.237	37.2 S	4.21S	0.027
			02	157S	78	131 S	31.1 S	0.237	37.2 S	4.21S	0.027
			03	157S	78	131 S	31.1 S	0.237	37.2 S	4.21S	0.027
1	02	002	01	38S	7	38.3S	12.0 S	0.313	11.9 S	4.50S	0.188
			02	38S	8	38.3S	11.4 S	0.298	11.3 S	4.00S	0.105
			03	38S	4	36.9S	3.30S	0.0894	3.40S	1.70S	0.045
			04	38S	1	a		0.254	9.65S	9.65S	0.254
			07	38S	7	38.3S	12.0 S	0.313	11.9 S	4.50S	0.188
			08	38S	8	38.3S	11.4 S	0.298	11.3 S	4.00S	0.105
			09	38S	1	a		0.254	9.65S	9.65S	0.254
			12	38S	8	38.3S	11.4S	0.298	11.3 S	4.00S	0.105
			13	38S	1	a		0.254	9.65S	9.65S	0.254
1	02	004	01	157S	78	131 S	31.1S	0.237	37.2 S	4.21S	0.0268
1	02	004	02	157S	78	131 S	31.1S	0.237	37.2 S	4.21S	0.027
			03	157S	78	131 S	31.1S	0.237	37.2 S	4.21S	0.027
1	03	002	05	38S	7	38.3S	12.0S	0.313	11.9 S	4.50S	0.188

a) Where n is 1 or 0, average C.V., is used.

b) No reference available, emission factor is treated as one observation.

c) No observation found in references, emission factor is treated as one observation.

Table 2.8(Continued) PRECISION OF SULFUR DIOXIDE EMISSION FACTORS FOR PRIORITY PROCESSES

SCC				Emission factor, Ef	No. of obs., n	Arith. mean, $\bar{x}$	Std. dev. of obs., s_m	Coeff. of variation, C. V.	Std. dev. of emission factor, S_f Ef x C.V.	Std. dev. of emission factor, E $\frac{S_f}{\sqrt{n}}$	Precision, P $\frac{E}{Ef}$
			06	38b	8	38.3b	11.4 b	0.298	11.3 b	4.00b	0.105
			09	38b	1	a		0.254	9.65b	9.65b	0.254
			13	38b	1	a		0.254	9.65b	9.65b	0.254
1	03	004	01	157b	78	131 b	31.1 b	0.237	37.2 b	4.21b	0.027
			02	157b	78	131 b	31.1 b	0.237	37.2 b	4.21b	0.027
			03	157b	78	131 b	31.1 b	0.237	37.2 b	4.21b	0.027
3	03	005	02	60	8	605	377	0.623	37.4	13.2	0.220
3	03	005	03	320	16	249	209	0.839	268	67.0	0.209
3	03	005	04	870	16	688	237	0.344	299	74.8	0.086
3	06	002	01	493	3	669	419	0.626	309	178	0.361

a) Where n is 1 or 0, average C.V., is used.
b) No reference available, emission factor is treated as one observation.
c) No observation found in references, emission factor is treated as one observation.

Table 2.9 PRECISION OF NITROGEN OXIDE EMISSION FACTORS FOR PRIORITY PROCESSES

SCC				Emission factor, EF	No. of obs., n	Arith. mean, $\bar{x}$	Std. dev. of obs., s_m	Coeff. of variation, C.V.	Std. dev. of emission factor, S_f EF x C.V.	Std. dev. of emission factor, E $\frac{S_f}{\sqrt{n}}$	Precision, P $\frac{E}{EF}$
1	01	002	01	30	12	16.4	3.25	0.198	5.94	1.71	0.057
			02	30	12	16.4	3.25	0.198	5.94	1.71	0.057
			03	55	3	36.3	29.4	0.810	44.6	25.7	0.467
			04	15	0	c		0.700	10.5	10.5	0.700
			06	30	12	16.4	3.25	0.198	5.94	1.71	0.057
			07	30	12	16.4	3.25	0.198	5.94	1.71	0.057
			08	15	0	c		0.700	10.5	10.5	0.700
			10	6	1	a		0.700	4.20	4.20	0.700
			12	30	12	16.4	3.25	0.198	5.94	1.71	0.057
1	01	004	01	105	477	100	109	1.09	114	5.22	0.050
			02	105	477	100	109	1.09	114	5.22	0.050
			03	105	477	100	109	1.09	114	5.22	0.050
1	01	006	01	600	28	409	104	0.254	152	28.7	0.048
			02	600	28	409	104	0.254	152	28.7	0.048
			03	600	28	409	104	0.254	152	28.7	0.048
1	02	002	01	30	12	16.4	3.25	0.198	5.94	1.71	0.057
			02	30	12	16.4	3.25	0.198	5.94	1.71	0.057
			03	55	3	36.3	29.4	0.810	44.6	25.7	0.467
			04	15	0	c		0.700	10.5	10.5	0.700
			07	30	12	16.4	3.25	0.198	5.94	1.71	0.057
			08	30	12	16.4	3.25	0.198	5.94	1.71	0.057
			09	15	0	c		0.700	10.5	10.5	0.700
1	02	002	12	30	12	16.4	3.25	0.198	5.94	1.71	0.057
			13	6	1	a		0.700	4.20	4.20	0.700
1	02	004	01	60	591	72.1	5.07	0.0703	4.22	0.174	0.003

a) Where n is 1 or 0, average C.V., is used.
b) No reference available, emission factor is treated as one observation.
c) No observation found in references, emission factor is treated as one observation.

Table 2.9(Continued) PRECISION OF NITROGEN OXIDE EMISSION FACTORS FOR PRIORITY PROCESSES

SCC				Emission factor, EF	No. of obs., n	Arith. mean, $\bar{x}$	St d. dev. of obs., s_m	Coeff. of variation, C. V.	St d. dev. of emission factor, S_f EF x C.V.	St d. dev. of emission factor, E $\frac{S_f}{\sqrt{n}}$	Precision, P $\frac{E}{EF}$
			02	60	591	72.1	5.07	0.0703	4.22	0.174	0.003
			03	60	591	72.1	5.07	0.0703	4.22	0.174	0.003
1	02	006	01	175	4	296	232	0.784	137	68.5	0.391
			02	175	4	296	232	0.784	137	68.5	0.391
			03	175	4	296	232	0.784	137	68.5	0.391
1	03	002	05	30	12	16.4	3.25	0.198	5.94	1.71	0.057
			06	30	12	16.4	3.25	0.198	5.94	1.71	0.057
			09	15	0	c		0.700	10.5	10.5	0.700
			13	6	1	a		0.700	4.20	4.20	0.700
1	03	004	01	60	591	72.1	5.07	0.0703	4.22	0.174	0.003
			02	60	591	72.1	5.07	0.0703	4.22	0.174	0.003
			03	60	591	72.1	5.07	0.0703	4.22	0.174	0.003
1	03	006	01	100	15	102	74.1	0.726	72.6	18.7	0.187
			02	100	15	102	74.1	0.726	72.6	18.7	0.187
			03	100	15	102	74.1	0.726	72.6	18.7	0.187
3	06	001	01	2900	1	a		0.700	2030	2030	0.700
			02	0.23	1	a		0.700	0.161	0.161	0.700
			03	69	1	a		0.700	48.3	48.3	0.700
			04	230	1	a		0.700	161	161	0.700

a) Where n is 1 or 0, average C.V., is used.

b) No reference available, emission factor is treated as one observation.

c) No observation found in references, emission factor is treated as one observation.

Table 2.10 PRECISION OF HYDROCARBON EMISSION FACTORS FOR PRIORITY PROCESSES

SCC				Emission factor, EF	No. of obs., n	Arith. mean, $\bar{x}$	St d. dev. of obs., s_m	Coeff. of variation, C. V.	St d. dev. of emission factor, S_f EF x C.V.	St d. dev. of emission factor, E $\frac{S_f}{\sqrt{n}}$	Precision, P $\frac{E}{EF}$
3	01	005	01	11500	0	c		0.921	10600	10600	0.921
4	02	001	01	1120	1	a		0.921	1030	1030	0.921
4	03	002	01	140	58	280	351	1.25	175	23.0	0.164
4	03	002	03	100	2	107	47.0	0.439	43.9	31.0	0.310

a) Where n is 1 or 0, average C.V., is used.
b) No reference available, emission factor is treated as one observation.
c) No observation found in references, emission factor is treated as one observation.

Table 2.11 PRECISION OF CARBON MONOXIDE EMISSION FACTORS FOR PRIORITY PROCESSES

SCC				Emission factor, EF	No. of obs., n	Arith. mean, $\bar{x}$	Std. dev. of obs., s_m	Coeff. of variation, C. V.	Std. dev. of emission factor, S_f EF x C.V.	Std. dev. of emission factor, E $\frac{S_f}{\sqrt{n}}$	Precision, P $\frac{E}{EF}$
3	01	005	01	33500	0	c		0.709	23800	23800	0.709
3	01	005	03	5300	2	8640	6900	0.799	4230	2990	0.564
3	01	005	04	4500	4	31900	16400	0.514	2310	1155	0.257
3	03	008	01	1750	2	1750	619	0.354	620	438	0.250
3	03	008	03	44	1	a		0.709	31.2	31.2	0.709
3	04	003	01	145	0	b		0.709	103	103	0.709
3	06	002	01	13700	1	a		0.709	9710	9710	0.709
3	06	003	01	3800	1	a		0.709	2690	2690	0.709

a) Where n is 1 or 0, average C.V., is used.
b) No reference available, emission factor is treated as one observation.
c) No observation found in references, emission factor is treated as one observation.

Table 2.12 AVERAGE PRECISION OF PARTICULATE EMISSION FACTORS

SCC	Emission factor, EF	No. of obs., n	Arith. mean, $\bar{x}$	St'd. dev. of obs., s_m	Coeff. of variation, C. V.	St'd. dev. of emission factor, S_f EF x C.V.	St'd. dev. of emission factor, E $\frac{S_f}{\sqrt{n}}$	Precision, P $\frac{E}{EF}$
1 01 002 01	13A	89	13.1A	3.61A	0.276	3.59A	0.381A	0.029
1 01 002 02	17A	34	18.3A	5.23A	0.286	4.86A	0.833A	0.049
1 01 002 04	13A	17	12.4A	6.77A	0.546	7.10A	1.72 A	0.132
3 05 002 01	45	5	38.8	10.7	0.276	12.4	5.55	0.123
3 05 003 04	0.07	3	0.07	0.0278	0.397	0.0278	0.0161	0.230
3 05 003 05	0.07	6	0.89	0.447	0.502	0.0351	0.0143	0.204
3 05 003 06	1.30	14	1.70	2.11	1.24	1.61	0.331	0.255
3 05 006 01	46	10	45.8	29.8	0.651	29.9	9.46	0.206
3 05 007 01	42.8	12	41.8	34.1	0.816	34.9	10.1	0.236
3 05 008 01	70	2	17.1	0.442	0.0258	1.81	1.28	0.018
3 05 016 04	200	4	134	70.1	0.523	105	52.5	0.263
3 06 002 01	242	2	166	185	1.11	269	190	0.785
							Avg.	= 0.211

Table 2.13 AVERAGE PRECISION OF SULFUR DIOXIDE EMISSION FACTORS

SCC	Emission factor, EF	No. of obs., n	Arith. mean, $\bar{x}$	St'd. dev. of obs., s_m	Coeff. of variation, C.V.	St'd dev. of emission factor, S_f EF x C.V.	St'd. dev. of emission factor, E $\frac{S_f}{\sqrt{n}}$	Precision, P $\frac{E}{EF}$
1 01 002 01	38S	7	38.3S	12.0 S	0.313	11.9 S	4.50S	0.118
1 01 002 02	38S	8	38.3S	1[illegible] S	0.298	11.3 S	4.00S	0.105
1 01 002 03	38S	4	36.9S	3.30S	0.0894	3.40S	1.70S	0.0448
1 01 004 01	157S	78	131 S	31.1 S	0.237	37.2 S	4.21S	0.0268
3 03 005 02	60	8	605	377	0.623	37.4	13.2	0.220
3 03 005 03	320	16	249	209	0.839	268	67.0	0.209
3 03 005 04	870	16	688	237	0.344	299	74.8	0.0860
3 06 002 01	493	3	669	419	0.626	309	178	0.36
							Avg.	= 0.146

Table 2.14 AVERAGE PRECISION OF NITROGEN OXIDE EMISSION FACTORS

SCC	Emission factor, EF	No. of obs., n	Arith. mean, $\bar{x}$	St'd. dev. of obs., s_m	Coeff. of variation, C. V.	St'd. dev. of emission factor, S_f EF x C.V.	St'd. dev. of emission factor, E $\frac{S_f}{\sqrt{n}}$	Precision, P $\frac{E}{EF}$
1 01 002 01	30	12	16,4	3,25	0,198	5,94	1,71	0,0570
1 01 002 03	55	3	36,3	29,4	0,810	44,6	25.7	0.467
1 01 004 01	105	477	100	109	1.09	114	5,22	0.0497
1 01 006 01	600	28	409	104	0,254	152	28.7	0,0478
1 02 004 01	60	591	72,1	5,07	0.0703	4,22	0.174	0.00290
1 02 006 01	175	4	296	232	0,784	137	68,5	0.391
1 03 006 01	100	15	102	74,1	0,726	72,6	18.7	0.187
							Avg.	= 0.172

Table 2.15 AVERAGE PRECISION OF HYDROCARBON EMISSION FACTORS

SCC	Emission factor, EF	No. of obs., n	Arith. mean, $\bar{x}$	St'd. dev. of obs., s_m	Coeff. of variation, C. V.	St'd. dev. of emission factor, S_f EF x C.V.	St'd. dev. of emission factor, E $\frac{S_f}{\sqrt{n}}$	Precision, P $\frac{E}{EF}$
4 03 002 01	140	58	280	351	1.25	175	23.0	0.164
4 03 002 03	100	2	107	47.0	0.439	43.9	31.0	0.310
							Avg.	= 0.237

Table 2.16 AVERAGE PRECISION OF CARBON MONOXIDE EMISSION FACTORS

SCC	Emission factor, EF	No. of obs., n	Arith. mean, $\bar{x}$	St'd. dev. of obs., s_m	Coeff. of variation, C. V.	St'd. dev. of emission factor, S_f EF x C.V.	St'd. dev. of emission factor, E $\frac{S_f}{\sqrt{n}}$	Precision, P $\frac{E}{EF}$
3 01 005 03	5300	2	8640	6900	0.799	4230	2990	0.564
3 01 005 04	4500	4	31900	16400	0.514	2310	1155	0.257
3 01 008 01	1750	2	1750	619	0.354	620	438	0.250
							Avg.	= 0.357

2.1.4 Precision of Emission Factors Determined by Method 4

Although it is not possible to calculate the precision of a guess, it is reasonable to estimate such precision. For example, given a specific process category, a guess cannot be any more precise than the most precise AP-42 factor within that category. As a practical matter, one cannot assume that a guess will be more precise than the least precise emission factor for the given category -- it may even be less precise. Since the exact precision cannot be determined, the unit emission factors used in calculating emissions by Method 4 were estimated to be as precise as the least precise AP-42 factor within that category.

2.1.5 Precision of Emission Factors Determined by Method 5

There is no basis for stating that an emission factor developed by, for example, a state air pollution control agency is any more precise than the corresponding AP-42 factor. Therefore an emission factor developed by a state or other agency is estimated to be as precise as the corresponding AP-42 factor. Where no AP-42 factor is given, but the process emits the pollutant in question, precision of the emission factor is estimated to be the same as that of a factor determined by guess (Method 4).

2.2 PRECISION OF CONTROL DEVICE EFFICIENCY VALUES

The precision of any value given for control device efficiency depends on how the number was derived by personnel completing the NEDS form. Methods for determining this three-digit number include the following:

a) Stack measurements before and after a control device.

b) Use of manufacturer's data.

c) Use of graphs for specific control devices relating efficiency to unit size, pressure drop, power requirements, and other parameters.

d) Estimation or guess.

Since there is no way of telling which of these methods led to the value entered on the NEDS data sheet, one must take a conservative approach in determining precision of values for control device efficiency.

The following guidelines were established:

1) All numbers not ending in .5 or .0, such as 92.3 or 76.6, have a precision of ± 0.1.

2) Numbers ending in .5, such as 75.5, have a precision of ± 0.3.

3) Numbers ending in .0 but not 0.0 or 5.0, such as 58.0, have a precision of ± 0.5.

4) Numbers less than 80 ending in 5.0, such as 55.0, have a precision of ± 5.0.

5) The numbers 85.0 and 95.0 have a precision of ± 2.5.

6) Numbers ending in 0.0, such as 50.0 or 90.0, have a precision of ± 5.0.

Statement 1) assumes that any number in this category must be fairly precise since it contains three significant figures. A properly conducted emission test yields values that are precise to the third significant figure.

Statement 2) considers values ending in 0.5, which can possibly be accurate to three significant figures, but also can be the average of two numbers (such as 84 and 89). A precision factor of ± 0.3 represents a conservative approach.

Statement 3) suggests that these numbers, usually from control system manufacturer's literature, are precise to the nearest unit, or ± 0.5.

Statement 4) and 6) assume conservatively that the entry may have been a guess or that the literature source states values in increments of 5 or 10. Therefore these numbers are assigned a precision of ± 5.0.

Statement 5) assumes that even though these numbers end in 5.0 and may have been determined by guess, entries of 80.0 or 90.0 would have preceded guesses of 85.0 and 95.0.

2.3 PRECISION OF THRUPUT VALUES

Instead of determining precision of a thruput value for each SCC, we assigned one precision to each major SCC category. Although the major categories include many different types of processes or fuels, the precisions are applied to the entire category.

A literature search was made to determine how specific industries in the major categories normally report their production or thruput. In addition, questionnaires were completed by the Directors and Executive Committee of the Air Pollution Control Association. These questionnaires provided estimates of typical thruput or production numbers for "average" installations in the major industries, along with the units and magnitudes in which the thruput or production is usually reported. With this information and engineering judgement, we developed precision values for thruput in each major SCC category.

The first major SCC category encompasses generation of electric power by burning of coal, gas, and oil. For various thruputs, X, the following precisions, P, were determined:

$$X \geq 200{,}000 \qquad P = \pm 0.001$$

$$10{,}000 \leq X < 200{,}000 \qquad P = \pm \frac{200}{X}$$

$$X < 10{,}000 \qquad P = \pm 0.001$$

Numbers greater than 10,000 in this category represent coal usage in major power plants; the precisions therefore reflect the precision of coal thruput values. The precision of numbers reported in this range is approximately ± 200. Thruput values greater than 200,000 have precisions less than 0.001, but the precision value was rounded to 0.001 since the precisions of emission factors are given only to three decimal places. Thruput values less than 10,000 usually indicate gas and oil usage. Since the reported thruputs of these fuels are quite precise, on the order of $\frac{\pm 10}{10,000}$, a precision of ± 0.001 is specified.

Another major SCC category is industrial boilers, whose reported thruputs are assigned the following precision values:

$X \geq 200,000$	$P = \pm 0.001$
$50,000 \leq X < 200,000$	$P = \pm \frac{500}{X}$
$1,000 \leq X < 50,000$	$P = \pm 0.020$
$X < 1,000$	$P = \pm 0.001$

Again, the small thruputs are considered precise since they represent mainly gas, oil and small coal boilers. The consumption of gas and oil can be known and reported very precisely. As the thruput values increase, coal usage begins to dominate and the precisions reflect the change. Thruputs in the range of 1,000 to 50,000 have a precision of $\pm \frac{500}{25,000}$ or 0.020. Thruputs in the range of 50,000 to 200,000 are precise within ± 500. For very large thruputs, the values should be known and reported precisely. Thruputs in this range are also ± 500; rounding off to three decimal places gives a precision of ± 0.001. Two other major categories, commercial/institutional boilers and in-process fuel usage, are assigned the same thruput precision values as industrial boilers.

The precision of thruput values for all stationary internal combustion sources is ± 0.002. This value is based on engineering judgment and consideration that the thruput is likely to be small, but not necessarily reported to the same precision as thruput of industrial boilers. The fuel normally used is gas or oil and the thruput is reported with a precision of $\frac{\pm 1}{500}$ or $\frac{\pm 5}{2500}$, which equals ± 0.002.

The precision of thruputs for all chemical processes is estimated to be ± 0.010. The category of chemical manufacturing encompasses a wide variety of types of processes and a large range of thruputs. Although the thruput or production in these industries is likely to be known to a high degree of precision, many operators are reluctant to divulge precise production figures because of competition within the industry. It is assumed, therefore, that the precision to which thruput is generally reported is $\frac{\pm 10}{1000}$ for small operations, $\frac{\pm 1,000}{100,000}$ for medium-sized processes, and $\frac{\pm 10,000}{1,000,000}$ for large operations; these values yield an overall precision of ± 0.010.

The precision of thruput reported in the food/agricultural category is estimated to be 0.100. Again, the category encompasses a wide variety of types of processes and it is judged that the thruput values reported for these processes are not as precise as those of some other industries. Country elevators often report their thruput with a precision of $\frac{\pm 50,000}{500,000}$ bushels and terminal elevators report thruputs of about $\frac{\pm 1,000,000}{10,000,000}$ bushels. A precision of ± 0.100 is assigned to the entire food/agricultural category.

Precision of thruputs for metallurgical (primary and secondary) processes is specified as follows:

$$X \geq 500,000 \qquad P = \pm 0.001$$

$$50,000 \leq X < 500,000 \qquad P = \pm \frac{500}{X}$$

$$X < 50,000 \qquad P = \pm 0.010$$

Precision of thruput values for large metallurgical processes is judged to be good, and for small installations, not as good. Thruputs of the magnitude 50,000 to 500,000 are reported within ± 500. Thruputs larger than 500,000 are still within ± 500, but the precision for this category is rounded to three decimal places, or 0.001. Thruputs less than 50,000 are as precise as those at 50,000. That is, thruputs of 25,000 have a precision of $\frac{\pm 250}{25,000}$ or ± 0.010.

The precision of thruputs for mineral product installations follows a similar trend:

$$X \geq 1,000,000 \qquad P = \pm 0.001$$

$$50,000 \leq X < 100,000 \qquad P = \pm \frac{1,000}{X}$$

$$10,000 \leq X < 50,000 \qquad P = \pm 0.020$$

$$X < 10,000 \qquad P = \pm 0.050$$

The large installations know and report their thruputs to a higher degree of precision than do the small ones. Thruputs greater than 50,000 are reported ± 1,000; precision of thruputs greater than 1,000,000 are rounded to 0.0001. Thruputs between 10,000 and 50,000 are generally reported with precisions in the range of $\frac{\pm 500}{25,000}$, or ± 0.020. Included among the small installations are seasonal rock crackers, for which the accounting of thruputs is not very precise, usually in the range of $\frac{\pm 250}{5,000}$ or ± 0.050.

Precision of thruput values for the petroleum industry is as follows:

$$\begin{array}{ll} X \geq 200,000 & P = \pm 0.001 \\ 1,000 \leq X < 200,000 & P = \pm \frac{200}{X} \\ X < 1,000 & P = \pm 0.002 \end{array}$$

This category includes both refinery operations and process heaters. Thruputs less than 1,000 represent the process heaters, whereas the larger thruputs represent refining operations. The larger the refinery capacity, the more precisely the thruput is reported. This trend was determined from analysis of information presented in National Petroleum News Factbook Issue. Precisions given for thruputs greater than 1,000 reflect the finding that the refinery capacities are generally reported ± 1,000 barrels per day. The precision values take into account conversion from barrels per day to thousands of barrels per year. Precisions of thruput values for the process heaters are all on the order of 500 or ± 0.002.

Precisions of thruput values for the wood products industries are:

$X \geq 10,000 \qquad P = \pm 0.010$

$X < 10,000 \qquad P = \pm 0.050$

This category includes both paper pulping and sawmill operations. With a break point of 10,000, a precision of ± 0.010 represents mainly pulping operations and a precision of ± 0.050 represents various sawmill operations. Thruputs for pulping operations are generally reported with a precision of $\frac{\pm 5,000}{500,000}$ or ± 0.010. Thruputs for sawmill operations are generally reported in board-feet and are then converted to tons for entry on the NEDS form. This conversion entails some additional imprecision. The thruputs entered on the NEDS forms therefore are assigned a precision of approximately $\frac{\pm 250}{5,000}$ or ± 0.050.

The precision of thruput values for metal fabrication, leather products, textile manufacturing and "other/not classified" categories is estimated to be ± 0.050. These are small, diverse, and relatively low-polluting industries. It is estimated that the precision of thruput values reported by any of these industries would not be better than the precision of the smallest thruput reported in any of the other major categories. Therefore, the precision assigned to these categories is an average of the precisions of the smallest thruputs of the other categories.

The precision of thruput values for all point source evaporation operations is ± 0.010. This category includes petroleum storage and surface coating (i.e., painting) among others. The precision of +0.010 is valid of all thruputs in this category. For small thruputs, the precision is $\frac{\pm 10}{1,000}$; for large thruputs the precision is $\frac{\pm 1,000}{100,000}$ or $\frac{\pm 10,000}{1,000,000}$. The precision of all these thruputs is ± 0.010.

The precision of thruput values for all solid waste disposal operations is estimated as follows:

$$\begin{array}{rl} X \geq 10,000 & P = \pm 0.100 \\ 1,000 \leq X < 10,000 & P = \pm 0.200 \\ X < 1,000 & P = \pm 0.500 \end{array}$$

Sources disposing of more than 10,000 tons per year usually are municipal incinerators, whose operations maintain records of the quantities burned. The precision of values for the amount burned is not very good, however, generally about $\frac{\pm 2,500}{25,000}$ or ± 0.100. Industrial and commercial incinerators burn less waste, and operators keep few, if any, records of the amounts burned. Generally, the less waste incinerated, the less precise the thruput. Thruputs for industrial incinerators often range from 1,000 to 10,000, with an approximate precision of $\pm \frac{1,000}{5,000}$ or ± 0.200. Thruputs of smaller units (generally commercial units or small industrial incinerators) are often estimated when reported for NEDS purposes. The resulting precision is in the range of $\pm \frac{250}{500}$ or ± 0.500.

Precisions assigned to thruput values for all categories are summarized in Table 2.17.

Table 2.17. PRECISION OF THRUPUT VALUES

SCC designation	Thruput, X	Precision, P
1 01 XXX XX (Electric generation)	$X \geq 200{,}000$	$P = \pm 0.001$
	$10{,}000 \leq X < 200{,}000$	$P = \pm \frac{200}{X}$
	$X < 10{,}000$	$P = \pm 0.001$
1 02 XXX XX (Industrial boilers)	$X \geq 200{,}000$	$P = \pm 0.001$
	$50{,}000 \leq X < 200{,}000$	$P = \pm \frac{500}{X}$
	$1{,}000 \leq X < 50{,}000$	$P = \pm 0.020$
	$X < 1{,}000$	$P = \pm 0.001$
1 03 XXX XX (Commercial/ institutional boilers)	$X \geq 200{,}000$	$P = \pm 0.001$
	$50{,}000 \leq X < 200{,}000$	$P = \pm \frac{500}{X}$
	$1{,}000 \leq X < 50{,}000$	$P = \pm 0.020$
	$X < 1{,}000$	$P = \pm 0.001$
2 XX XXX XX (Internal Combustion engine)	All X	$P = \pm 0.002$
3 01 XXX XX (Chemical manufacture)	All X	$P = \pm 0.010$
3 02 XXX XX (Food/agricultural)	All X	$P = \pm 0.100$
3 03 XXX XX 3 04 XXX XX (Metallurgical)	$X \geq 500{,}000$	$P = \pm 0.001$
	$50{,}000 \leq X < 500{,}000$	$P = \pm \frac{500}{X}$
	$X < 50{,}000$	$P = \pm 0.010$
3 05 XXX XX (Mineral products)	$X \geq 1{,}000{,}000$	$P = \pm 0.001$
	$50{,}000 \leq X < 1{,}000{,}000$	$P = \pm \frac{1{,}000}{X}$
	$10{,}000 \leq X < 50{,}000$	$P = \pm 0.020$
	$X < 10{,}000$	$P = \pm 0.050$

Table 2.17 (Continued). PRECISION OF THRUPUT VALUES

SCC designation	Thruput, X	Precision, P
3 06 XXX XX	$X \geq 200,000$	$P = \pm 0.001$
(Petroleum industry)	$10,000 \leq X < 200,000$	$P = \pm \frac{200}{X}$
	$X < 10,000$	$P = \pm 0.001$
3 07 XXX XX	$X \geq 10,000$	$P = \pm 0.010$
(Wood products)	$X < 10,000$	$P = \pm 0.050$
3 09 XXX XX	All X	$P = \pm 0.050$
(Metal fabrication)		
3 20 XXX XX	All X	$P = \pm 0.050$
(Leather products)		
3 30 XXX XX	All X	$P = \pm 0.050$
(Textile manufacturing)		
3 90 XXX XX	$X \geq 200,000$	$P = \pm 0.001$
(In-process fuel)	$50,000 \leq X < 200,000$	$P = \pm \frac{500}{X}$
	$1,000 \leq X < 50,000$	$P = \pm 0.020$
	$X < 1,000$	$P = \pm 0.001$
3 99 XXX XX	All X	$P = \pm 0.050$
(Other/not classified)		
4 XX XXX XX	All X	$P = \pm 0.010$
(Point source evaporation)		
5 XX XXX XX	$X \geq 10,000$	$P = \pm 0.100$
(Solid waste disposal)	$1,000 \leq X < 10,000$	$P = \pm 0.200$
	$X < 1,000$	$P = \pm 0.500$

2.4 PRECISION OF VALUES FOR ASH AND SULFUR CONTENT OF FUEL

2.4.1 Anthracite and Bituminous Coal

Users of large quantities of coal periodically test the fuel's sulfur content by a procedure developed by the American Society for Testing Materials (ASTM). Even though the test procedure is relatively simple, results vary because of retention of sulfate sulfur in the ash and degree of precision with which the sample is weighed. The ASME Power Test Code for Solid Fuels, PTC 3.2-1954,[1] Par. 69 specifies that reproducibility of results of ash and sulfur content determinations shall be as follows:

Coal characteristics	Permissible differences when tested in different laboratories, absolute percent
TEST FOR ASH	
No carbonates present	0.3
Carbonates present	0.5
More than 12% ash, containing carbonate and pyrite	1.0
TEST FOR SULFUR	
Sulfur - under 2 percent	0.10
Sulfur - over 2 percent	0.20

Smith and Gruber report that the average ash content of coals from the major producing districts is always less than 12 percent and that two carbonate compounds occur frequently in coal. It is assumed that carbonates are present in all coals represented on the NEDS form. Precision of reported ash contents can then be expressed as follows:

Reported ash content	Precision
$\leq$ 12.0 %	$\pm \frac{0.5}{\% A}$
> 12.0 %	$\pm \frac{1.0}{\% A}$

Precision of the reported sulfur contents of solid fuels can be expressed as follows:

Reported sulfur content	Precision
< 2.0 %	$\pm \frac{0.10}{\% S}$
$\geq$ 2.0 %	$\pm \frac{0.20}{\% S}$

2.4.2 Distillate and Residual Oil

As with solid fuels, the ASTM specifies the testing of oils to determine sulfur content. The ASME Power Test Code for liquid fuels, PTC 3.1-1958[6] specifies reproducibility of results of sulfur content determination as follows:

Sulfur content, percent	Reproducibility by different operator and apparatus, (absolute deviation from mean, percent)
0 to 0.5	0.03
over 0.5 to 1.0	0.04
over 1.0 to 2.0	0.05
over 2.0 to 3.0	0.07
over 3.0 to 4.0	0.09
over 4.0 to 5.0	0.12
over 5.0	0.14

The precision of reported contents of oils can be expressed by the following equation:

Reported sulfur content	Precision
$S \leq 0.5$	$\pm \frac{0.03}{\% S}$
$0.5 < S \leq 1.0$	$\pm \frac{0.04}{\% S}$
$1.0 < S \leq 2.0$	$\pm \frac{0.05}{\% S}$
$2.0 < S \leq 3.0$	$\pm \frac{0.07}{\% S}$
$3.0 < S \leq 4.0$	$\pm \frac{0.09}{\% S}$
$4.0 < S \leq 5.0$	$\pm \frac{0.12}{\% S}$
$S > 5.0$	$\pm \frac{0.14}{\% S}$

2.4.3 Liquefied Petroleum Gas

The standard method of test for total sulfur in fuel gases is specified per ASTM Designation D1072-56[2]. The absolute precision of this method as determined by ASTM is ± 0.1 grain of sulfur per cubic feet. This is equivalent to ± 0.0001 absolute percent sulfur by weight. The precision of any reported value of sulfur content (reported in percent on the NEDS form) is therefore:

$$\text{Precision} = \pm \frac{0.0001}{\% S}$$

3.0 PRECISION OF AREA SOURCE EMISSION VALUES

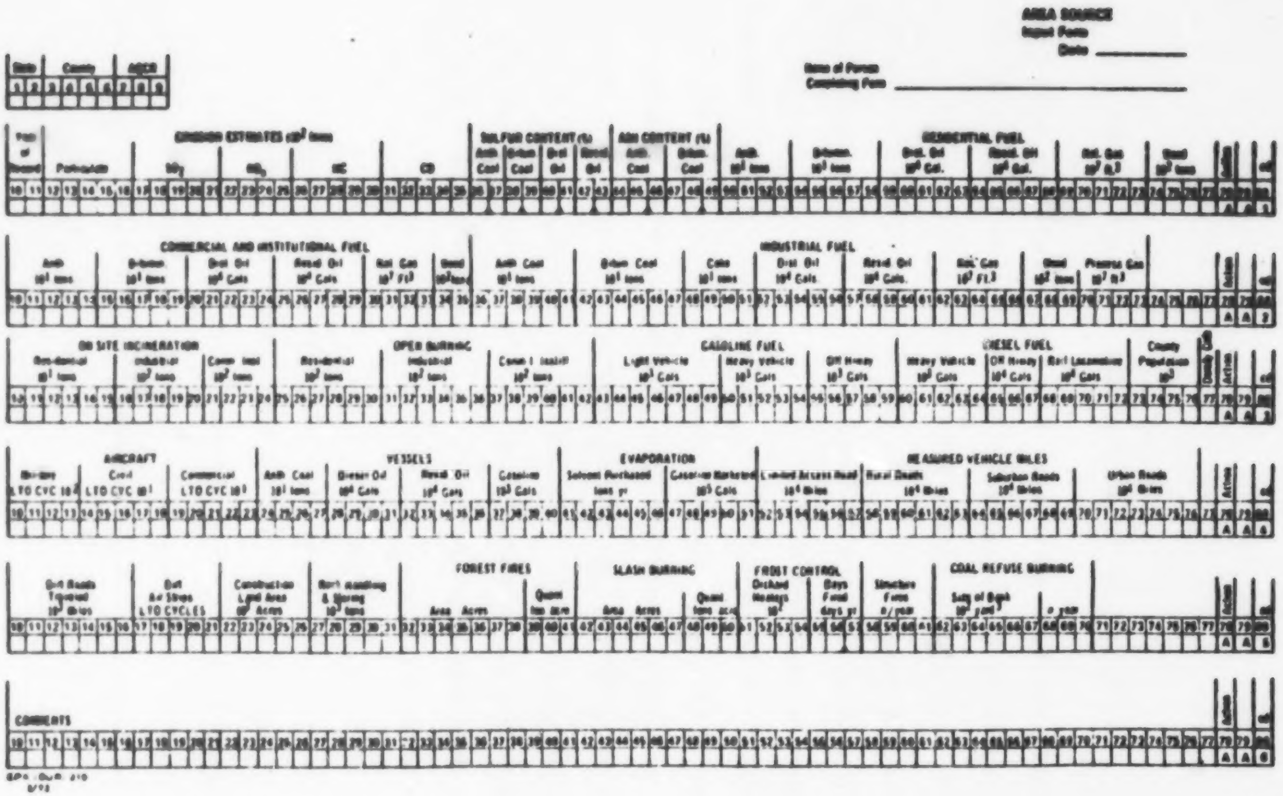
Emissions from area sources are calculated by use of the appropriate AP-42 emission factors and data entered on the NEDS area source coding form (Figure 3.1). In this section, the emission factors, categorized as nonautomotive and automotive, and the NEDS input data entries are analyzed to determine the precision values.

3.1 PRECISION OF NONAUTOMOTIVE AREA SOURCE EMISSION FACTORS

The area source emission factors used in the NEDS computer program are taken from EPA Report AP-42. Where the area source emission factor (or category) corresponds to a point source emission factor, the precision determined for the corresponding point source emission factor is also applied to the area source emission factor. Precisions of the area source emission factors are tabulated in Table 3.1.

3.1.1 Priority Pollutants

The priority area source pollutants (nonautomotive) are particulate, SO_x, and NO_x from industrial combustion of bituminous coal, NO_x from commercial and institutional combustion of natural gas, HC from solvent evaporation and gasoline marketing, and HC and CO from off-highway gasoline usage.



AREA SOURCE
Input Form
Date ______

Name of Person
Completing Form ______

EMISSION ESTIMATES

SULFUR CONTENT (%)

ASH CONTENT (%)

RESIDENTIAL FUEL

COMMERCIAL AND INSTITUTIONAL FUEL

INDUSTRIAL FUEL

ON SITE INCINERATION

OPEN BURNING

GASOLINE FUEL

DIESEL FUEL

AIRCRAFT

VESSELS

EVAPORATION

MEASURED VEHICLE MILES

FOREST FIRES

SLASH BURNING

FROST CONTROL

COAL REFUSE BURNING

COMMENTS

Figure 3.1. Area source coding form.

Table 3.1 PRECISION OF AREA SOURCE UNIT EMISSION FACTORS

Category	SCC number used	Pollutant				
		Particulate	SO_2	NO_x	HC	CO
Anthracite Coal						
Residential	10300109	0.211	0.146	0.172	0.237	0.357
Commercial/Inst.	10300109	0.211	0.146	0.172	0.237	0.357
Industrial	10300109	0.211	0.146	0.172	0.237	0.357
Bituminous Coal						
Residential	10300214	0.211	0.146	0.172	0.237	0.357
Commercial/Inst.	10300209 10300213	0.132	0.254	0.700	0.237	0.357
Industrial	10200209	0.132[a]	0.254[a]	0.700[a]	0.237	0.357
Distillate Oil						
Residential	10300503	0.211	0.146	0.172	0.237	0.357
Commercial/Inst.	10300502	0.211	0.146	0.172	0.237	0.357
Industrial	10200502	0.211	0.146	0.172	0.237	0.357
Residual Oil						
Residential	10200402	0.211	0.027	0.003	0.237	0.357
Commercial/Inst.	10200402	0.211	0.027	0.003	0.237	0.357
Industrial	10200402	0.211	0.027	0.003	0.237	0.357

a) Priority area source.

Table 3.1 (continued). **PRECISION OF AREA SOURCE UNIT EMISSION FACTORS**

Category	SCC number used	Pollutant				
		Particulate	SO_2	NO_x	HC	CO
Natural Gas						
Residential	10300603	0.211	0.146	0.187	0.237	0.357
Commercial/Inst.	10300603	0.211	0.146	0.187	0.237	0.357
Industrial	10200602	0.211	0.146	0.391[a]	0.237	0.357
Wood - all categories	10200902	0.211	0.146	0.172	0.237	0.357
Process Gas-Indus.	10200602	0.211	0.146	0.391	0.237	0.357
On-Site Incineration						
Residential	50200102	0.211	0.146	0.172	0.237	0.357
Commercial	50200101 50200102	0.211	0.146	0.172	0.237	0.357
Industrial	502001 (01-02)	0.211	0.146	0.172	0.237	0.357
Open Burning						
Residential	50300202	0.211	0.146	0.172	0.237	0.357
Commercial	50300202	0.211	0.146	0.172	0.237	0.357
Industrial	50300202	0.211	0.146	0.172	0.237	0.357
Evaporation						
Solvent		--	--	--	0.000[a]	--

[a] Priority area source.

Table 3.1 (continued). PRECISION OF AREA SOURCE UNIT EMISSION FACTORS

Category	SCC number used	Pollutant				
		Particulate	SO_2	NO_x	HC	CO
Evaporation (cont'd.)						
Gasoline marketing		--	--	--	0.921[a]	--
Dirt Roads		NYD	--	--	--	--
Dirt Airstrips		NYD	--	--	--	--
Construction		NYD	--	--	--	--
Rock Handling & Storage		NYD	--	--	--	--
Forest Fires		NYD	NYD	NYD	NYD	NYD
Slash Burning	50100202	0.208	--	0.172	0.237	0.357
Frost Control		NYD	NYD	NYD	NYD	NYD
Structure Fires		NYD	NYD	NYD	NYD	NYD
Coal Refuse Burning		NYD	NYD	NYD	NYD	NYD
Off Highway						
Gasoline		0.211	0.146	0.172	0.044[a]	0.028[a]
Diesel		0.211	0.146	0.172	0.237	0.357
Rail Locomotive		0.211	0.146	0.172	0.237	0.357

[a] Priority area source.
NYD = Emission factor not yet defined.

Table 3.1 (continued). **PRECISION OF AREA SOURCE UNIT EMISSION FACTORS**

Category	SCC number used	Pollutant				
		Particulate	SO_2	NO_x	HC	CO
Aircraft						
Military		0.211	0.146	0.172	0.237	0.357
Civil		0.211	0.146	0.172	0.237	0.357
Commercial		0.211	0.146	0.172	0.237	0.357
Vessels						
Bituminous coal		0.211	0.146	0.172	0.237	0.357
Distillate oil		0.211	0.146	0.172	0.237	0.357
Residual oil		0.211	0.146	0.172	0.237	0.357
Gasoline		0.211	0.146	0.172	0.237	0.357
Coke - Industrial		NYD	NYD	NYD	NYD	NYD

NYD = Emission factor not yet defined.

3.1.1.1 Area Source Combustion - The priority pollutants from area source combustion are also priority pollutants from point sources of combustion. Calculations determining the precision of the area source emission factors (as in the section on point source emission factors) are shown in Table 3.2.

3.1.1.2 Evaporation - The emission factor for solvent evaporation is 2000 lb/ton, which means that the amount of solvent purchased for a given operation is equal to the amount needed to make up evaporation losses. Therefore, any imprecision is entailed in the estimate of the amount of solvent purchased, and the emission factor of 2000 lb/ton is considered precise.

An AP-42 emission factor is given for HC from gasoline marketing. Since this is a priority area source emission factor, it is handled in the same manner as a priority point source emission factor. Calculation of precision of these factors is given in Table 3.2.

3.1.1.3 Off-Highway Gasoline Usage - Emission factors for off-highway gasoline usage are assumed to have been derived from factors for emissions from heavy-duty, gasoline-powered (HDG) highway vehicles. Using the HDG emission rates as the source of the emission factors for off-highway gasoline usage may affect the accuracy of the off-highway emission factors, but does not affect the precision. Therefore, the precision values for HDG emission rates are used in calculating the precision of off-highway gasoline emission factors.

Table 3.2 PRIORITY NONAUTOMOTIVE AREA SOURCE POLLUTANTS

Category	Pollutant	Emission factor, EF	No. of obs., n	Arith. mean, $\bar{x}$	St'd. dev. of obs., s_m	Coeff. of variation, C.V.	St'd. dev. of emission factor, S_f EF x C.V.	St'd. dev. of emission factor, E $\frac{S_f}{\sqrt{n}}$	Precision, P $\frac{E}{EF}$
Industrial bituminous coal combustion	Part[d]	13A	17	12.4A	6.77A	0.546	7.10A	1.72A	0.132
	SO_x[d]	38S	1	a		0.254	9.65S	9.65S	0.254
	NO_x[d]	15	0	a,c		0.700	10.5	10.5	0.700
Industrial natural gas combustion	NO_x[d]	180	4	296	232	0.784	141	70.5	0.391
Solvent evaporation loss (misc.)	HC	2000							0.000[e]
Gasoline marketing	HC	21 lb/10^3 gal.	0	a,c		0.921	19.4	19.4	0.921
Off-highway, gasoline	HC	553							0.044[f]
	CO	3030							0.028[f]

a) Where n is 1 or 0, average C.V., is used.
b) No reference available, emission factor is treated as one observation.
c) No observation found in references, emission factor is treated as one observation.
d) Also a priority point source pollutant.
e) Based on the assumption that all of the solvent evaporates.
f) Based on the precision of HDG emission factors.

Precision of emission factors for CO from off-highway gasoline usage is assumed to be equal to that of the emission factor for uncontrolled (pre-1970 model year) HDG exhaust. This precision value, discussed in detail in a later section on automotive factors (Section 3.3.2.1), is calculated as follows:

$$\text{Precision}_{CO} = \left[\frac{\text{Var }(C_i)}{(C_i)^2}\right]^{1/2} = [0.00081]^{1/2} = 0.028$$

The emission factor for HC from off-highway gasoline usage is calculated as the sum of the HC in uncontrolled HDG exhaust and combined HC emissions from crankcase and evaporation. Thus the variance of the off-highway HC emission rate is equal to the sum of the variances of the uncontrolled HDG exhaust and combined crankcase and evaporation HC emission rates:

$$\begin{aligned}\text{Var (Off-Highway HC)} &= \text{Var }(C_{HDG-HC}) + \text{Var }(f_{HDG-HC}) \\ &= 0.272 + 0.952 \\ &= 1.224\end{aligned}$$

The precision of the emission factor for HC from off-highway gasoline usage is therefore:

$$\text{Precision}_{HC} = \left[\frac{\text{Var(Off-Highway HC)}}{(C_{HDG-HC} + f_{HDG-HC})^2}\right]^{1/2} = \left[\frac{1.224}{(17 + 8.2)^2}\right]^{1/2} = 0.044$$

3.1.2 Non-Priority Pollutants

Emission factors for all other area sources are given the precision of the corresponding point source emission factor. When there is no corresponding point source emission factor, the area source is assigned the average precision that was determined for point source emission factors. Precision values are given in Table 3.1.

3.2 PRECISION OF AREA SOURCE CODING FORM ENTRIES

The purpose of this section is to define a precision for every entry on the NEDS area source coding form, excluding the emission estimates. The coding form and the entries are discussed in detail in EPA's "Guide for Compiling a Comprehensive Emission Inventory"[7], published as APTD-1135. When used in conjunction with the precision ratings of the emission factors, the precision values for NEDS entries will define a quality rating of the area source emission values in an emission inventory.

For all entries on the area source coding form, the method of determination is assumed to be correct. The precision of the entry is then dependent on the precisions of the factors used to determine the entry. For instance, if an entry X is a function of factors A, B, and C according to the equation:

$X = (A)(B)(C)$ then the precision of X (P_x) is a function of the precisions of the individual factors as follows:

$$P_x = \sqrt{P_a^2 + P_b^2 + P_c^2}$$

For the cases in which APTD-1135 provides several methods for determining a single entry, precisions are calculated only for the method believed to be most widely used. For a factor whose precision varies over a wide range of values dependent on the size of the factor, a median value is used in determining precision.

All entries entail rounding errors. The units of each information field on the coding form define what rounding off, if any, must be performed. For example, if values to be entered in a field are expressed in units of 10^4 gallons, the entry should be considered precise within ± 5 x 10^3 gallons. In addition to the rounding errors, the precision of the data-gathering techniques must be considered. When the precision of data-gathering techniques is zero, the precision of rounding is used. When a precision other than zero is assigned to the data-gathering techniques, that precision is used for the entry on the coding form.

Precisions of entries on the NEDS area source coding form are summarized in Table 3.3.

3.2.1 County Data

3.2.1.1 Population - County population figures are obtained from the 1970 Census of Population.[8] The Bureau of the Census reports almost complete coverage in the 1970 census. They report the population to an exact number, much more precise than the nearest thousand coded on the NEDS form. The precision therefore depends only on the significant figures reported. For this field the precision equals ±500 divided by the entry.

Table 3.3 SUMMARY OF THE PRECISIONS OF ENTRIES

ON THE NEDS AREA SOURCE CODING FORM

Card	Columns	Precision of entry	Comments
1	50-53	+ 0.196	(for a zero in Card 1, Columns 54-58)
		+ 0.045	(for an entry or blank in Card 1, Columns 54-58)
1	54-58	+ 0.196	(for a zero in Card 1, Columns 50-53)
		+ 0.045	(for an entry or blank in Card 1, Columns 50-53)
1	59-63	+ 0.104	
1	64-68	+ 0.144	
1	69-73	+ 0.054	
1	74-77	+ 0.555	
2	10-14	+ 0.615	(for a zero in Card 2, Columns 36-41)
		+ 0.637	(for an entry or blank in Card 2, Columns 36-41)
2	15-19	+ 0.294	
2	20-24	+ 0.312	
2	25-29	+ 0.144	
2	30-33	+ 0.050	
2	34-35	+ 0.269	
2	36-41	+ 0.664	
2	42-47	+ $1.26 \times 10^2 (\text{entry})^{-.97}$	
2	48-51	+ 0.150	
2	52-56	+ 0.023	
2	57-61	+ 0.023	
2	62-66	+ 0.127	
2	67-69	+ 0.250	
2	70-73	+ 0.200	
3	10-15	+ 10.00	
3	16-20	+ 10.00	
3	21-24	+ 10.00	
3	25-30	+ 10.00	
3	31-35	+ 10.00	

Table 3.3 (continued). SUMMARY OF THE PRECISION OF ENTRIES ON THE MEDS AREA SOURCE CODING FORM

Card	Columns	Precision of entry	Comments
3	37-42	± 10.000	
3	43-49	± 0.045	(for an entry in Card 4, Columns 52-76) Variable G_1
		± 0.071	(for no entry in Card 4, Columns 52-76) Variable G_1
3	50-54	± 0.045	(for an entry in Card 4, Columns 52-76) Variable G_2
		± 0.072	(for no entry in Card 4, Columns 52-76) Variable G_2
3	55-59	$\frac{[0.022T^2 - .572\,TP + 28.73\,P^2]^{1/2}}{T}$ where T = entry in Card 3, Columns 55-59, and P = entry in Card 3, Columns 73-76	
3	60-64	$\pm \frac{0.5}{\text{entry}}$	Variable G_3
3	65-67	± 0.082	
3	68-72	± 0.100	
3	73-76	$\pm \frac{500}{\text{entry}}$	
3	77	precise number, p = 0.000 Variables P_u and P_R	
4	10-13	$\pm \frac{0.5}{\text{entry}}$	
4	14-18	$\pm \frac{0.5}{\text{entry}}$	
4	19-23	$\pm \frac{0.5}{\text{entry}}$	
4	24-27	± 0.030	
4	28-31	± 0.130	
4	32-36	± 0.180	
4	37-40	± 0.158	
4	41-46	for the entry in Card 3, Columns 73-76 in the range: 0 to 100....................± 0.936 100 to 500....................± 0.484 500 to 1000....................± 0.246 1000 to 9999....................± 0.165	

Table 3.3 (continued). SUMMARY OF THE PRECISION OF ENTRIES ON THE NEDS AREA SOURCE CODING FORM

Card	Columns	Precision of entry	Comments
4	47-51	$\pm$ 0.060	
4	52-57	$\pm$ 0.032	Variable M_1
4	58-63	$\pm$ 0.032	Variable M_2
4	64-69	$\pm$ 0.032	Variable M_3
4	70-76	$\pm$ 0.032	Variable M_4
5	10-16	$\pm$ 0.503	
5	17-21	$\pm$ 0.000	
5	22-26	$\pm \frac{0.5}{\text{entry}}$	
5	27-31	$\pm \frac{0.5}{\text{entry}}$	
5	32-38	$\pm$ 0.050	
5	39-41	$\pm$ 0.150	
5	42-47	$\pm \frac{50}{\text{entry}}$	
5	48-50	$\pm$ 0.250	
5	51-54	$\pm \frac{0.5}{\text{entry}}$	Position 385-388
5	55-57	$\pm \frac{5.0}{\text{entry}}$	Position 389-391
5	58-61	$\pm \frac{5.0}{\text{entry}}$	
5	62-67	$\pm$ 0.270	
5	68-70	precise number, $p = 0.000$	

3.2.1.2 Density Code - The 1970 census also classifies urban and rural populations in a county as a percentage urban. This percentage is precise based on the classification specified by the Bureau of Census. Since APTD-1135[7] defines a code for each percentage, no variation is introduced, and the density code is a precise number.

3.2.2 Sulfur Content

APTD-1135[7] specifies using a weighted average for sulfur content of fuels consumed in a county. This averaging creates serious problems in determining precision. To simplify the determination, assume that fuels consumed by different categories of users have the same sulfur content countywide. This is a logical assumption, since most coal used in a given area is mined from the same general region.

3.2.2.1 Anthracite and Bituminous Coal - The precision of tests for determining sulfur content of coal is discussed in Section 2.4.1, which specifies that precisions of the sulfur content of solid fuels can be expressed as follows:

Reported sulfur content	Precision
$< 2.0\%$	$\pm \frac{0.10}{\%S}$
$\geq 3.0\%$	$\pm \frac{0.20}{\%S}$

3.2.2.2 Distillate and Residual Oil - The precision of tests for determining sulfur content of fuel oil is discussed in Section 2.4.2. Precisions of the sulfur content of fuel oil can be expressed as follows:

Reported sulfur content,%	Precision
$S \leq 0.5$	$\pm \frac{0.03}{\% S}$
$0.5 < S \leq 1.0$	$\pm \frac{0.04}{\% S}$
$1.0 < S \leq 2.0$	$\pm \frac{0.05}{\% S}$
$2.0 < S \leq 3.0$	$\pm \frac{0.07}{\% S}$
$3.0 < S \leq 4.0$	$\pm \frac{0.09}{\% S}$
$4.0 < S \leq 5.0$	$\pm \frac{0.12}{\% S}$
$S > 5.0$	$\pm \frac{0.14}{\% S}$

3.2.3 Ash Content

Again, APTD-1135[7] specifies using a weighted average to determine ash content of coals over an entire county. In this case, also, assume that the ash content is constant over the county. The ash contents for anthracite and bituminous coal are determined in the same manner if ASTM procedures are followed, as discussed in Section 2.4.1. Accordingly, precision of the ash content value reported on the NEDS form may be expressed as follows:

Reported ash content,%	Precision
≤ 12.0	$\pm \frac{0.5}{\% A}$
> 12.0	$\pm \frac{1.0}{\% A}$

3.2.4 Residential Fuel

For most fuels, residential fuel usage is determined by apportioning statewide fuel totals to residential categories and then apportioning the residential categories to counties on the basis of dwelling units per county heating with the fuel.

3.2.4.1 Anthracite Coal - Residential consumption of anthracite is usually determined on the basis of the number of dwelling units heating with coal as enumerated by the 1970 Census of Housing.[9] The average consumption per dwelling unit is the product of the coal heating requirement factor[7], the average annual heating degree-days from Local Climatological Data[10], and a correction factor for the median number of rooms per dwelling unit in the county versus the national median of 5.0 rooms per dwelling unit.[9] The calculated residential usage of coal must be compared with the statewide area source totals, determined by subtracting the point source consumption of anthracite from the total state consumption of anthracite given by the Bureau of Mines.[11] If the calculated residential usage of coal should exceed the statewide area source usage of anthracite, consider the statewide usage as the residential consumption of anthracite. Assume that the difference between the calculated residential usage of coal and the area source consumption of anthracite represents the residential consumption of bituminous coal. The precision of the entry for residential consumption of anthracite coal will depend on precisions of the factors used in the determination.

Number of dwelling units heating with coal - This figure is obtained from the 1970 Census of Housing[9] under "House Heating Fuel". This source gives a county-by-county enumeration of houses heated with various types of fuel. The figure is obtained from a 5 percent sample of all the housing units nationwide. The Census of Housing provides tables for calculation of the approximate standard error based on the percent sampled and the number of housing units in the area. Since the standard error varies from county to county, we generalize a precision value based on data from the states of Ohio, Michigan, Kentucky, and Iowa. See Appendix A.

precision = ± 0.14

Coal heating requirement factor - This factor represents the coal required to heat an average 5-room dwelling for one degree-day. The factor cited in APTD-1135 is 0.0012 ton coal per dwelling unit per degree-day. Calculating by the method in Appendix B we obtain:

Type House	Factor
Insulated	0.001097 ton coal/D.U.-D.D.
Noninsulated	0.00161 ton coal/D.U.-D.D.

Analysis based on these values indicates that the factor cited in APTD-1135 was derived by assuming that 80 percent of households heating with anthracite coal are insulated.

Factor = 0.8 (0.001097) + 0.2 (0.00161) = 0.0012

Assume that 66.7 percent of the values occur in the range from 100 percent insulated to 60 percent insulated and that this range represents two standard deviation units.

	Factor
100% insulated	0.001097
60% insulated	0.0013022

$$\text{standard deviation} = \frac{0.0013022 - 0.001097}{2} = 0.0001026$$

$$\text{precision} = \frac{0.0001026}{0.0012} = \pm\ 0.084$$

Annual heating degree-days - Degree-days are obtained from local meteorological data on average 24-hour temperatures by defining a degree-day as a day where the average 24-hour temperature is 1 degree below 65°F. Temperature may be measured very precisely. Considering a 0.5-degree error in the significant range of 10 degrees or greater below 65°, we get a maximum error of ± 0.05.

Correction factor for number of rooms per dwelling unit in the study area - This factor is based on a 20 percent sample of all households and therefore should be precise within the limits of the reported units. Since this value is reported to the nearest tenth, rounding off errors would give ± 0.05 or less. The precision would then be $\pm \frac{0.05}{5}$. The 5.0 in the denominator is a precise figure since it is the basis for calculation of heat loss. Therefore, precision = ± 0.01.

Total statewide area source consumption of anthracite coal - The precision of this factor depends on the precision of the state consumption totals in Minerals Yearbook[11] and the precision of the state point source totals. The state totals are reported to the nearest ton and at least four significant figures. Consider this as a precise number, since the worst case is precise within + 0.0001. The reported point source consumption is based on information from each point source. The precision depends on the number of significant figures reported. Most point sources report at least three significant figures. Assuming this is the case, the precision equals $\pm \frac{0.5}{100} = \pm 0.005$. Assuming that the point source total accounts for no more than 90 percent of the state totals, the precision of the area source totals is ± 0.045.

Overall precisions - Two cases must be considered in determining the overall precision of the anthracite coal entry.

> Case 1: Anthracite coal is the only coal used as residential fuel (a zero will appear for residential bituminous coal consumption). The consumption of anthracite is the product of the factors developed above. Overall precision (P_o) is determined as follows:
>
> $$P_o^2 = P_1^2 + P_2^2 + P_3^2 + P_4^2$$
>
> $$P_o^2 = (0.17)^2 + (0.084)^2 + (0.05)^2 + (0.01)^2$$
>
> $$P_o^2 = 0.03856$$
>
> $$P_o = \pm 0.196$$
>
> Case 2: Both anthracite and bituminous coals are used by residential sources. In this case the residential anthracite consumption equals the difference between the Bureau of Mines figure and the point source totals. This precision, calculated above, equals ± 0.045.

3.2.4.2 Bituminous Coal - Essentially the same procedures and factors are used for calculating residential consumption of bituminous coal as for calculating residential consumption of anthracite coal; the same precisions apply. Two cases are considered for bituminous coal:

> Case 1: Bituminous coal is the only coal used as residential fuel (a zero will appear for residential anthracite coal consumption. This total is determined by the product of the factors defined in Section 3.2.4.1. The precision will be the same as determined for Case 1 in Section 3.2.4.1 and equals ± 0.196.
>
> Case 2: Both anthracite and bituminous coal are consumed by residential sources. The figure is calculated by determining total coal usage and subtracting the total area source consumption of anthracite (assuming only residential sources). The precision is dependent on the factors in Section 3.2.4.1, but since a subtraction is involved, an assumption must be made as to the contribution from each factor. The equation used to determine bituminous coal usage is:

$$B = T - A$$

where B = bituminous coal usage

A = anthracite coal usage

T = total coal usage

From Section 3.2.4.1 the precision of $T = \pm 0.196$ and

the precision of $A = \pm 0.045$

If it is assumed that anthracite consumption accounts for no more than 80 percent of the total coal consumption ($A \leq 0.8T$), the maximum error possible would be:

$$\pm 0.196T \pm 0.045\ (0.8T)$$

$$\text{or } \pm 0.241T$$

The precision of B, based on the maximum error and $B \pm 0.2T$, is

$$\frac{\pm 0.241T}{0.2T} = \pm 1.205$$

3.2.4.3 Distillate Oil - Residential consumption of distillate oil is determined by the same procedures outlined with regard to anthracite coal. The only factors that differ are the number of dwelling units heating with fuel oil and the oil heating requirement factor.

Number of dwelling units heating with fuel oil - This figure is obtained by the same procedure outlined for anthracite coal calculations. The calculation of standard error is based on a generalization of data from Ohio, Michigan, Kentucky, and Iowa, as in Appendix A.

precision = ± 0.06

Oil heating requirement factor - This factor represents the amount of oil required to heat an average 5-room dwelling for 1 degree-day. The value is given as 0.18 gallon oil per dwelling unit per degree-day. According to Appendix B (ASHRAE Handbook values):

Type House	Factor
Insulated	0.16847 gal oil/D.U.-D.D.
Noninsulated	0.26578 gal oil/D.U.-D.D.

Most oil-heated homes are insulated; upon analysis, the factor appears to represent a distribution of 88 percent insulated and 12 percent noninsulated homes. Since we have no data on the actual ratio of insulated to noninsulated homes for different counties, an assumption must be made. If we assume that for 68 percent of the counties the range is 75 to 100 percent insulated homes and that this range represents two standard deviation units, we get:

	Factor
100% insulated	0.16847
75% insulated	0.1927975

$$\text{standard deviation} = \frac{0.1927975 - 0.16847}{2} = 0.0122$$

$$\text{precision} = \frac{0.0122}{0.18} = \pm\ 0.068$$

Overall precision - Precision of the value for residential consumption of distillate oil is equal to the product of precisions of the factors for degree-days (0.05) and rooms-per-dwelling (0.01, both from Section 3.2.4.1) and the factors for number of dwelling units heating with distillate oil and oil heating requirements as just calculated. The precision is then:

$$P_o^2 = (0.05)^2 + (0.01)^2 + (0.06)^2 + (0.068)^2$$

$$P_o^2 = 0.010824$$

$$P_o = \pm\ 0.104$$

3.2.4.4 Residual Oil - Residual oil is not usually burned in residential furnaces. If it is used within the area of the inventory, however, contact the local fuel dealers to determine what percentage of their customers are sold residual oil. The percentage is applied to the total amount of oil consumed by residential users (with precision of 0.104, determined above) to calculate gallons of residual oil. Assume that the dealers are precise within 10 percent when reporting the distribution of oil. Precision of the value for residual oil consumption is then determined as follows:

$$P_o^2 = (0.104)^2 + (0.10)^2$$

$$P_o^2 = 0.020816$$

$$P_o = \pm 0.144$$

3.2.4.5 Natural Gas - Natural gas consumption by residential users is reported by state in Reference 13. The Bureau of Mines states that these reports are obtained by direct contact with dealers and others; they assert that these contacts account for 80 percent of the gas produced and that most of the remaining gas is accounted for in marketing reports of the companies contacted. The statewide totals are apportioned to the county by the ratio of county/state dwelling units heating with natural gas. If we assume that the Bureau of Mines statement implies that at least three-fourths of the remaining 20 percent of natural gas usage is accounted for, then the precision of the value for residential natural gas consumption per state is ± 5 percent. The precision of the number of dwelling units per county heating with natural gas, calculated according to Appendix A, is ± 0.02. The precision of the number of dwelling units per state heating with natural gas is also calculated according to Appendix A by using the average number of dwelling units per state and consulting Reference 10. The precision is ± 0.001. The overall precision is then:

$$P_o^2 = (0.05)^2 + (0.02)^2 + (0.001)^2$$

$$P_o^2 = 0.002901$$

$$P_o = \pm 0.054$$

3.2.2.6 Wood - The procedures outlined with regard to anthracite coal consumption are used again in determining residential consumption of wood. The two factors that differ are the number of dwelling units heating with wood and the wood requirement factor.

Number of dwelling units heating with wood - This figure is obtained by the same procedure used earlier for other fuels. The calculation of standard error is based on a generalization of data from Ohio, Michigan, Kentucky, and Iowa, as in Appendix A.

$$\text{precision} = \pm\ 0.42$$

Wood heating requirement factor - This factor represents the wood required to heat an average 5-room dwelling for 1 degree-day. The value given in APTD-1135 is 0.0017 ton of wood per dwelling unit per degree-day. According to Appendix B (ASHRAE Handbook values):

Type House	Factor
Insulated	0.00189 ton wood/D.U.-D.D.
Noninsulated	0.00286 ton wood/D.U.-D.D.

These factors are higher than that given in APTD-1135. If it is assumed that the APTD value is the result of two observations, the precision may be calculated:

$$\sigma' = \frac{0.00286 - 0.00189}{1.13} = 8.6 \times 10^{-4}$$

$$\sigma_{\bar{x}} = \frac{8.6 \times 10^{-4}}{\sqrt{2}} = 6.1 \times 10^{-4}$$

$$\text{precision} = \frac{6.1 \times 10^{-4}}{0.0017} = \pm\ 0.358$$

Overall precision - Precision of the value for residential consumption of wood is equal to the product of precisions of the factors for degree-days (0.05) and rooms-per-dwelling (0.01, both from Section 3.2.4.1) and the factors for number of dwelling units heating with wood and wood heating requirements, as just calculated. The precision is then:

$$P_o^2 = (0.05)^2 + (0.01)^2 + (0.42)^2 + (0.358)^2$$

$$P_o^2 = 0.3072$$

$$P_o = \pm 0.554$$

3.2.5 Commercial and Institutional Fuel

For most fuels, commercial and institutional use is determined by obtaining statewide totals from Bureau of Mines publications and apportioning to county on the basis of population.

3.2.5.1 Anthracite Coal - Commercial institutional use of anthracite coal is determined by subtracting statewide residential use of anthracite from the total statewide area source consumption of anthracite and apportioning the balance to county on the basis of population. The precisions of the values for statewide residential consumption and total area source consumption of anthracite were determined in Section 3.2.3.4. Also, the precisions for county and state population figures were determined earlier, and both are precise values. The overall precision is then the precision of the number representing the difference between residential usage and total area source usage. Assuming that residential sources consume 75 percent of the anthracite, the precision is determined as follows:

$$T = A - R$$

where T = commercial institutional consumption of anthracite

A = total area source consumption of anthracite

R = residential consumption of anthracite

$$\frac{\text{Var (T)}}{T^2} = \frac{\text{Var (A)} + \text{Var (R)}}{(A - R)^2}$$

$$\text{Var (A)} = (0.045A)^2$$

$$\text{Var (R)} = (0.196)^2$$

but $R = 0.75A$

$$\frac{\text{Var (T)}}{T^2} = \frac{(0.045A)^2 + (0.147A)^2}{(A - 0.75A)^2}$$

$$\frac{\text{Var (T)}}{T^2} = \frac{0.0236A^2}{0.0625A^2}$$

$$\frac{\sigma\text{ (T)}}{T} = \frac{0.154A}{0.25A}$$

but $0.25A = T$

therefore $\frac{\sigma\text{ (T)}}{T} = \frac{0.154\ (4T)}{T}$

precision = $\pm$ 0.615

This precision value applies only to cases where no anthracite is consumed by industrial sources. For cases where anthracite is consumed by industrial sources, first subtract statewide residential usage from total area source usage, then assign 60 percent of that balance to the commercial institutional category and 40 percent to the industrial category. Multiplying by 60 percent reduces the precision of the entry. Assuming that 60 percent is precise within 10 percent gives an overall precision as follows:

$$P_o^{\,2} = (P_1)^2 + (\tfrac{10}{60})^2$$

$$P_o^{\,2} = (0.615)^2 + (0.167)^2$$

$$P_o^{\,2} = 0.4061$$

$$P_o = \pm\, 0.637$$

3.2.5.2 Bituminous Coal - The value for commercial institutional consumption of bituminous coal is the difference between the Bureau of Mines figure for statewide consumption of bituminous coal (obtained from retail dealers) and the residential consumption of bituminous coal, apportioned to counties on the basis of population.

The Bureau of Mines figure represents almost complete coverage of coal producers. The figure should be precise within the nearest thousand tons as reported. The error would be ± 500 tons. Based on a median value of 193 thousand tons for retail dealers distribution of bituminous coal in the state, the precision equals 193,000 or ± 0.003. The precision of the population figures is zero (Section 3.2.1). The precision of the value for residential usage of bituminous coal has also been determined; assuming no anthracite coal consumption, it is ± 0.196. The overall precision is dependent on precision of the percentage of coal consumed by residential sources. Assuming that residential consumption represents 60 percent of the retail dealers figure gives the following precision:

$$T = D - R$$

where T = commercial institutional consumption of bituminous coal

D = retail dealers figure from Bureau of Mines

R = residential consumption of bituminous coal

$$\frac{\text{Var (T)}}{T^2} = \frac{\text{Var (D)} + \text{Var (R)}}{(D - R)^2}$$

but $R = 0.6D$

$$\text{Var (D)} = (0.002D)^2$$

$$\text{Var (R)} = (0.196)^2 = (0.1176D)^2$$

$$\frac{\text{Var (T)}}{T^2} = \frac{(0.002D)^2 + (0.1176D)^2}{(0.4D)^2}$$

$$\frac{\text{Var (T)}}{T^2} = \frac{0.01383376D^2}{0.16D^2}$$

$$\text{precision} = \frac{\sigma\ (T)}{T} = \pm\ 0.294$$

3.2.5.3 Distillate Oil - Commercial and institutional distillate oil consumption is the difference between residential consumption and the sum of the figures given for "distillate-type heating oils", "kerosene used for heating", and "distillate used by the military" from Tables 5, 6, and 12 of Reference 12. The difference is then apportioned to county on the basis of population.

The Bureau of Mines totals represent essentially complete coverage of oil producers. The figures should be precise within the nearest thousand barrels for each category. The median values for each category are 532,000 barrels "kerosene used for heating"; 3,339,000 barrels - "distillate-type heating oils"; and 96,000 barrels - "distillate used by the military." Assuming the maximum error equal to the standard deviation in each case, the precision is calculated.

$$T = K + D + M_d$$

where T = total use of distillate for heating

K = kerosene used for heating

D = distillate-type heating oils

M_d = distillate used by the military

$\sigma\ (K) = \pm\ 500$ barrels

$\sigma\ (D) = \pm\ 500$ barrels

$\sigma\ (M) = \pm\ 500$ barrels

$$\frac{\text{Var }(T)}{T^2} = \frac{\text{Var }(K) + \text{Var }(D) + \text{Var }(M_d)}{(K + D + M)^2}$$

$$\frac{\text{Var }(T)}{T^2} = \frac{3(500)^2}{(T^2)}$$

$$\text{Var }(T) = 750{,}000$$

$$\sigma\ (T) = 866$$

$$\frac{\sigma\ (T)}{T} = \frac{866}{(3{,}339{,}000 + 96{,}000 + 532{,}000)}$$

$$\text{precision} = \frac{\sigma(T)}{T} = \pm\ 0.0002$$

For most cases the totals are essentially precise figures. Imprecision is introduced in determining the difference between the totals and residential consumption. Assuming that residential sources account for 75 percent of the distillate used for heating, the precision is calculated as follows:

$$C - I = T - R$$

C - I = commercial institutional area source consumption of distillate oil

T = distillate oil - total area source consumption

R = residential consumption of distillate oil

$$\frac{\mathrm{Var}\ (C - I)}{(C - I)^2} = \frac{\mathrm{Var}\ (T) + \mathrm{Var}\ (R)}{(T - R)^2}$$

$\sigma\ (R) = 0.104R$ (Section 3.2.4.3)

$$R = 0.75T$$

$$\frac{\mathrm{Var}\ (C - I)}{(C - I)^2} = \frac{(0.0002T)^2 + (0.08T)^2}{(0.25T)^2}$$

$$\frac{\mathrm{Var}\ (C - I)}{(C - I)^2} = \frac{0.00000004 + 0.0061}{0.0625}$$

$$\frac{\mathrm{Var}\ (C - I)}{(C - I)^2} = 0.097$$

$$\frac{\sigma\ (C - I)}{(C - I)} = 0.312$$

Apportionment to county on the basis of population adds no imprecision, therefore

precision = ± 0.312

3.2.5.4 Residual Oil - The value for commercial and institutional usage of residual oil is the difference between the amount of residential consumption and the sum of the figures given for "residual-type heating oils" and "residual used by the military" from Tables 7 and 12 of Reference 12. The difference is then apportioned to counties on the basis of population.

As mentioned earlier, the Bureau of Mines figures should be precise within ± 500 barrels for each category. The median values for each category are 561,000 barrels - "residual-type heating oils" and 103,000 barrels - "residual used by the military." Assuming that the maximum error is equal to the standard deviation in each case, the precision is calculated:

$$T = R + M_R$$

where T = total residual used for heating

R = "residual-type heating oils"

M_R = "residual used by the military"

$$\frac{\text{Var }(T)}{T^2} = \frac{\text{Var } R + \text{Var } M_R}{(R + M_R)^2}$$

$$\frac{\text{Var }(T)}{T^2} = \frac{2(500)^2}{T^2}$$

$$\text{Var }(T) = 500{,}000$$

$$\sigma\ (T) = 707$$

$$\frac{\sigma\ (T)}{T} = \frac{707}{(561{,}000 + 103{,}000)}$$

$$\frac{\sigma\ (T)}{T} = .0011$$

Again calculation of the residential consumption of residual oil introduces imprecision into the totals for commercial institutional consumption. Assuming that residential sources account for 50 percent of the residual used for heating, the precision is calculated as follows:

$$C - I = T - A_R$$

C - I - commercial institutional consumption of residual oil by area sources

T = residual oil - total area source consumption

A_R = residential consumption of residual oil

$$\frac{\mathrm{Var}\ (C - I)}{(C - I)^2} = \frac{\mathrm{Var}\ (T) + \mathrm{Var}\ (A_R)}{(T - A_R)^2}$$

$\sigma\ (A_R) = 0.144A_R$ (Section 3.2.4.4)

$A_R = 0.5T$

$$\frac{\mathrm{Var}\ (C - I)}{(C - I)^2} = \frac{(0.0011T)^2 + (0.072T)^2}{(0.5T)^2}$$

$$\frac{\mathrm{Var}\ (C - I)}{(C - I)^2} = \frac{0.00000121 + 0.005184}{0.25}$$

$$\frac{\mathrm{Var}\ (C - I)}{(C - I)^2} = 0.02074$$

$$\frac{\sigma\ (C - I)}{C - I} = 0.144$$

precision = ± 0.144

3.2.5.5 Natural Gas - Commercial institutional usage of natural gas is the sum of values given for "commercial" and "other users" in Table 6 of Reference 13. The total is apportioned to counties on the basis of population.

The Bureau of Mines figures should be precise within ± 5 percent. Apportioning to counties on the basis of population should add no imprecision. Therefore, the overall precision is ± 0.05.

3.2.5.6 Wood - A figure for commercial institutional consumption of wood can be entered only if adequate local data from fuel dealers or other reliable sources are available. Quantities of wood are usually reported in units of cords. Since cords measure volume rather than weight, any variability in density of the wood would affect the precision of the weight reported. Reference 22 reports that densities of wood vary by more than 20 pounds per cubic foot. Assuming that the wood in a given location differs by only 10 pounds from an average density of 40 pounds per cubic foot gives a precision equal to $\frac{10}{40}$ or ± 0.25. The quantity of wood reported also entails imprecision. Fuel dealers should give figures precise within 10 percent. The overall precision of the value for commercial institutional consumption of wood is then:

$$P_o^2 = (0.25)^2 + (0.10)^2$$

$$P_o^2 = 0.0725$$

$$P_o = \pm 0.269$$

3.2.6 Industrial Fuel

For most categories, usage of industrial fuel by area sources is calculated by subtracting state totals for point source consumption from Bureau of Mines data and apportioning the balance to counties according to a ratio of the number of manufacturing employees in the county to the total number of manufacturing employees in the state.

3.2.6.1 Anthracite Coal - The total consumption of anthracite coal by industrial users per state is determined in the same manner as consumption by commercial institutional users except that the factor for industrial usage is 40 percent rather than 60. The total is then apportioned to counties on the basis of the total number of manufacturing employees per county.

Industrial area source consumption of anthracite per state - Precision of this figure is calculated in the same way as the value for commercial institutional usage with the exception of the 40 percent factor:

$$P^2 = (0.615)^2 + \left(\frac{10}{40}\right)^2$$

$$P^2 = 0.4407$$

$$P = \pm 0.664$$

Number of manufacturing employees - This figure is obtained for county and state from Bureau of Census data (Reference 15). This census encompassed all establishments employing one or more persons during the census year (1967) and thus includes all sources considered as industrial in the scope of the NEDS system. Since an industrial firm can accurately report the number of employees, and since all firms were contacted, the census figure should be accurate.

But the Census Bureau reports employees to the nearest hundred, leading to a maximum error in the county total of ± 50 employees. If we assume that the error is random, the state total will also have a maximum error of ± 50 employees. Because of the variability of numbers of employees in different counties and states, we assume that the precision of median values will apply to all cases. The median value for a state is 175,000 employees. The precision of this value is $\frac{50}{175,000}$ or ± 0.0003. The median value for a county is 2150 employees. The precision of this value is $\frac{50}{2150}$ or ± 0.023. Since the factor for number of employees is county totals divided by state totals, the precision of the factor is:

$$P^2 = P_1^{\,2} + P_2^{\,2}$$

$$P^2 = (0.0003)^2 + (0.023)^2$$

$$P = \pm 0.023$$

Overall precision - The overall-precision figure for industrial usage of anthracite coal is the product of precisions of the factors just calculated for industrial area source consumption and number of manufacturing employees. The precision is then:

$$P_o^{\,2} = (0.664)^2 + (0.023)^2$$

$$P_o^{\,2} = 0.4414$$

$$P_o = \pm 0.664$$

3.2.6.2 Bituminous Coal - First the total statewide industrial consumption of bituminous coal is determined by consulting the Minerals Yearbook[11] Table 40, pg. 357, under the category "All Others." To determine industrial area source consumption, use the value for statewide industrial point source usage, taking care that coal used for processes (i.e. coke oven charge) is not included. Subtract that value from the total statewide industrial coal combustion to determine the amount of bituminous coal burned by industrial area sources over the state. This figure is then apportioned to counties by assuming that industrial fuel usage in a county is proportional to the total number of manufacturing employees in that county. The number of manufacturing employees for state and county is obtained from the 1967 Census of Manufacturers, "Area Statistics."[15]

In summary, industrial area source combustion of bituminous coal for a county is determined as follows:

$$A_{B.C.} = [I_{B.C.} - P_{B.C.}] \left(\frac{E_c}{E_s}\right)$$

where:

$A_{B.C.}$ = industrial area source combustion of bituminous coal per county

$I_{B.C.}$ = state total combustion of bituminous coal by industrial users

$P_{B.C.}$ = point source combustion of bituminous coal for the state

E_c = number of manufacturing employees in the county

E_s = number of manufacturing employees in the state

Industrial source consumption of bituminous coal by state[11] - This figure is based on data collected quarterly by the Bureau of Mines from coal handlers who normally sell or produce 100,000 tons or more of coal annually. Reports from these coal handlers are said to cover 94 percent of all coal shipped or produced. The balance is estimated by statistical methods, and the data should be reliable, at least within the limits of the units reported in the table (1,000 tons). For any one state, the maximum error in $I_{B.C.}$ would be ± 500 tons.

Point source combustion of bituminous coal by state - This factor is the summation of the coal usage reported by all industrial point sources. Reports of the amount of coal burned are usually in round figures. Since a source usually has accurate figures for the coal burned, precision depends on the number of significant figures reported, which is usually two or three. In such cases the maximum error would be:

± 5% for two significant figures

± 0.5% for three significant figures

For consistency with the units of $I_{B.C.}$, consider that the point source usage is reported to the nearest 1,000 tons. Assuming random error distribution, the maximum error is ± 500 tons.

Number of manufacturing employees per county and state[15] - The referenced census encompassed all establishments employing one or more persons during the census year

(1967) and this includes all sources considered as industrial in the scope of the NEDS system. Since an industrial firm can accurately report the number of employees and since all firms were contacted, the census figure should be accurate. But the Census Bureau reports employees to the nearest hundred, leading to a maximum error in E_c of ± 50 employees. If we assume that the error is random, the state total will also have a maximum error of ± 50 employees.

Overall precision - To determine the overall precision for area source industrial consumption of bituminous coal assume the maximum error in a factor equals the standard deviation of that factor. For:

$$A_{B.C.} = [I_{B.C.} - P_{B.C.}] \left(\frac{E_c}{E_s}\right)$$

$$\text{Var } A_{B.C.} = A_{B.C.}^2 \left[\frac{\text{Var}(I_{D.C.} - P_{B.C.})}{(I_{B.C.} - P_{B.C.})^2} + \frac{\text{Var } Ec}{E_c^2} + \frac{\text{Var } Es}{E_s^2} \right]$$

but $\text{Var } (I_{B.C.} - P_{B.C.}) = \text{Var } (I_{B.C.}) + \text{Var } (P_{B.C.})$

therefore: $\text{Var } A_{B.C.} = A_{B.C.}^2 \left[\frac{\text{Var. } (I_{B.C.}) + (\text{Var } (P_{B.C.})}{(I_{B.C.} - P_{B.C.})^2} + \right.$

$$\left. \frac{\text{Var } E_c}{E_c^2} + \frac{\text{Var } E_s}{E_s^2} \right]$$

since $\frac{\sigma(A)}{A} = \frac{(\text{Var } (A))^{½}}{A}$

$$\frac{\sigma(A_{B.C.})}{A_{B.C.}} = \left[\frac{\text{Var } (I_{B.C.}) + \text{Var } (P_{B.C.})}{(I_{B.C.} - P_{B.C.})^2} + \frac{\text{Var } E_c}{E_c^2} + \frac{\text{Var } E_s}{E_s^2} \right]^{½}$$

Calculating $\frac{\sigma(A_{B.C.})}{A_{B.C.}}$ for several cases according to Appendix C, we obtain the following general equation to define a precision of the area source entry for industrial bituminous coal consumption.

$$\text{precision} = \frac{\sigma(A_{B.C.})}{A_{B.C.}} = 1.26 \times 10^{2} \, (A_{B.C.})^{-0.97}$$

3.2.6.3 Coke - Consumption of coke by area sources can be determined only when local information is available. These data usually come directly from the companies using the coke, who should have reliable figures for annual consumption. Estimating the figures to be precise at least to within ± 15 percent, the precision is ± 0.15.

3.2.6.4 Distillate Oil - The industrial area source use of distillate oil statewide is the sum of figures given for "industrial" and "oil companies" in Tables 8 and 9 of Reference 12 (Bureau of Mines) minus the amount consumed by industrial point sources. State totals are then apportioned to counties on the number of manufacturing employees.

The Bureau of Mines totals should be precise within the limits of the nearest thousand barrels for each category. The median values for each category are 662,000 barrels for "industrial" and 74,000 barrels for "oil companies". Assuming that the precision of the median cases applies to all cases gives:

$$T = I + O$$

where: T = total consumption of distillate oil by industrial users per state

I = industrial consumption of distillate oil

O = consumption of distillate oil by oil companies

$$\frac{\text{Var (T)}}{T^2} = \frac{\text{Var (I)} + \text{Var (O)}}{(I + O)^2}$$

$\text{Var (I)} = (500)^2$

$\text{Var (O)} = (500)^2$

$I + O = 662{,}000 + 74{,}000 = 736{,}000$

$$\frac{\text{Var (T)}}{T^2} = \frac{5 \times 10^5}{5.41696 \times 10^{11}} = 9.2 \times 10^{-7}$$

$$\frac{\sigma\ (T)}{T} = 9.6 \times 10^{-4}$$

precision $= \pm\ 0.00096$

Consumption of distillate oil by industrial point sources is reported to the nearest thousand gallons. Since most companies keep records of purchases of fuel oil, the figures should be precise within 500 gallons. Assuming that the point source consumption is around 60 percent of the total distillate oil consumption, precision may be determined for the median case.

$$P_p = \frac{500}{0.6(736{,}000)42}$$

$$P_p = \pm\ 2.7 \times 10^{-5}$$

The precision of values derived by apportioning to counties on the basis of manufacturing employees was determined in Section 3.2.6.

$P_M = 0.023$

The overall precision is determined as follows:

$$A_D = [T_D - P_D] \left(\frac{E_c}{E_s}\right)$$

where A_D = industrial area source consumption of distillate oil

T_D = total consumption of distillate oil by industrial users

P_D = consumption of distillate oil by point sources

E_c = number of manufacturing employees per county

E_s = number of manufacturing employees per state

$$\frac{\text{Var }(A_D)}{A_D^2} = \frac{\text{Var }(T_D) + \text{Var } P_D}{(T_D - P_D)^2} + \frac{\text{Var }(E_c)}{E_c^2} + \frac{\text{Var }(E_s)}{E_s^2}$$

$$\frac{\text{Var }(E_c)}{E_c^2} + \frac{\text{Var }(E_s)}{E_s^2} = (0.023)^2$$

using median values

$$\text{Var }(T_D) = (\pm\ 5 \times 10^5)42^2 \text{ gallons}^2$$

$$\text{Var }(P_D) = (\pm\ 500 \text{ gallons})^2$$

$$\frac{\text{Var }(A_D)}{A_D^2} = \frac{8.8 \times 10^8 \times 2.5 \times 10^5}{[(736000)42 - 18547200]^2} + (0.023)^2$$

$$\frac{\text{Var }(A_D)}{A_D^2} = \frac{8.8025 \times 10^8}{1.5288827 \times 10^{14}} + 5.29 \times 10^{-4}$$

$$\frac{\text{Var }(A_D)}{A_D^2} = 5.3476 \times 10^{-4}$$

$$\text{precision} = \frac{\sigma\ (A_D)}{A_D} = \pm\ 0.023$$

3.2.6.5 Residual Oil - The area source use of residual oil statewide is the sum of figures given for "industrial" and "oil companies" in Tables 8 and 9 of Reference 12, minus the amount consumed by industrial point sources. State totals are then apportioned to counties on the basis of the number of manufacturing employees.

Precisions are the same as for distillate oil calculations, but the median values change. On the basis of 950,000 barrels for "industrial" and 178,000 barrels for "oil companies", the precision of the state totals is $\pm 4 \times 10^{-7}$. Precision of the point source totals is $\pm 1.8 \times 10^{-5}$. The overall precision is then:

$$P_o = \left[\frac{\text{Var }(T_R) + \text{Var }(P_R)}{(T_R - P_R)^2} + (0.023)^2\right]^{1/2}$$

where T_R = total industrial consumption of residual oil

P_R = point source consumption of residual oil

using median values

$$\text{Var }(T_R) = 8.82 \times 10^8$$

$$\text{Var }(P_R) = 2.5 \times 10^5$$

$$(T_R - P_R)^2 = (1.89504 \times 10^7)^2$$

$$(T_R - P_R)^2 = 3.6 \times 10^{14}$$

$$P_o = \left[\frac{8.82 \times 10^8 \times 2.5 \times 10^5}{3.6 \times 10^{14}} + 5.29 \times 10^{-4}\right]^{\frac{1}{2}}$$

$$P_o = \pm 0.023$$

3.2.6.6 Natural Gas - To determine total area source consumption of natural gas by industrial consumers, the total statewide industrial consumption of natural gas is determined from Table 5, p. 734 of the Minerals Yearbook under the category "Industrial". Next we consult the point source inventory to obtain industrial point source consumption for the state. The difference between total statewide industrial usage and statewide industrial point source usage is the statewide industrial area source usage of natural gas. This figure is apportioned to counties by assuming that county industrial fuel usage is proportional to the number of manufacturing employees per county. The number of manufacturing employees for state and county is obtained from the 1967 Census of Manufacturers "Area Statistics."

In summary, the determination of industrial usage of natural gas attributable to area sources is as follows:

$$A_{N.G.} = \left[I_{N.G.} - P_{N.G.} \right] \left(\frac{E_c}{E_s} \right)$$

where $A_{N.G.}$ = industrial area source combustion of natural gas per county

$I_{N.G.}$ = total statewide usage of natural gas by industrial firms

$P_{N.G.}$ = statewide point source combustion of natural gas

E_c = number of manufacturing employees in the county

E_s = number of manufacturing employees in the state

Statewide usage of natural gas by industrial firms - These data are based on annual surveys of the companies that distribute natural gas; these surveys account for 80 percent of the natural gas produced. Most of the remaining natural gas usage is covered in the purchase listings of the reporting companies. Assuming that the figure reported covers 95 percent of the natural gas consumed, the precision is ± 0.05.

Statewide point source combustion of natural gas by industrial users - This value is the summation of the natural gas usage reported by all the industrial point sources in the state. It is usually reported in round numbers in units of 10^6 cubic feet. Since the amount of gas used is a readily available, accurate figure, precision will depend on the number of significant figures reported. A value reported to the nearest million cubic feet gives

$$\sigma\ (P_{N.G.}) = \pm\ 0.5 \times 10^6\ ft^3$$

Number of manufacturing employees per county and per state - The precision for E_c/E_s, determined earlier, is ± 0.023.

D. Overall Precision - For

$$A = (I - P)\left(\frac{E_c}{E_s}\right)$$

$$Var\ (A) = A^2 \left[\frac{Var\ (I) + Var\ (P)}{(I - P)^2} + \frac{Var\ (E_c)}{(E_c)^2} + \frac{Var\ (E_s)}{(E_s)^2}\right]$$

but Var (I - P) = Var (I) + Var (P)

$$Var\ (A) = A^2 \left[\frac{Var\ (I) + Var\ (P)}{(I - P)^2} + \frac{Var\ (E_c)}{(E_c)^2} + \frac{Var\ (E_s)}{(E_s)^2}\right]$$

$$\left[\frac{Var\ (E_c)}{(E_c)^2} + \frac{Var\ (E_s)}{(E_s)^2}\right] = (0.023)^2$$

Assume that the precision for the median value of $I_{N.G.}$ applies to all cases. The median value of $I_{N.G.}$ from the Minerals Yearbook is 86,682 x 10^6 cubic feet.

$$\sigma\ (I_{N.G.}) = 0.05\ I_{N.G.}$$

$$\mathrm{Var}\ (I_{N.G.}) = (0.05\ I_{N.G.})^2$$

$$\mathrm{Var}\ (I_{N.G.})_{median} = 1.878 \times 10^{19}$$

Assume that point sources account for 60 percent of the natural gas consumed by industrial users.

$$P_{N.G.\ median} = 0.6\ (86682 \times 10^6)$$

$$(P_{N.G.}) = 0.5 \times 10^6$$

$$\mathrm{Var}\ (P_{N.G.}) = 2.5 \times 10^{11}$$

$$\frac{\mathrm{Var}\ (A_{N.G.})}{(A_{N.G.})^2} = \frac{1.878 \times 10^{19} + 2.5 \times 10^{11}}{(3.46728 \times 10^{10})^2} + (0.023)^2$$

$$\frac{\mathrm{Var}\ (A_{N.G.})}{A_{N.G.}} = 1.56 \times 10^{-2} + 5.29 \times 10^{-4}$$

$$\text{precision} = \frac{\sigma\ (A_{N.G.})}{A_{N.G.}} = \pm\ 0.127$$

3.2.6.7 Wood - Usage of wood by industrial sources not classified as point sources must be estimated from data supplied by these sources. Although a company may provide a good estimation of the feed rate to their boiler, error may be introduced if the density of the wood is not constant. Accounting for this type of error, assume that the estimation is precise within 25 percent and precision is ± 0.25.

3.2.6.8 Process Gas - Use of process gas by industrial area sources can be determined only from local information. The most common users of process gas are petroleum refining operations and natural gas production plants. They usually cannot provide a measurement in cubic feet but can supply their heater or boiler capacity. Because of the varying heat content of process gas, the volume of gas required to fire the heater or boiler to capacity also varies. At best the number provided by the user is an estimate, which should be precise within 20 percent.

$$P = \pm 0.20$$

3.2.7 On-Site Incineration

On-site incineration refers to the disposal of solid waste in small incinerators, such as backyard burners, industrial incinerators, and incinerators at food and department stores, hospitals, and schools. Per-capita generation rates are derived from the 1968 National Survey of Community Solid Waste Practices[16,17] which provides a good indication of the methods of solid waste disposal but a poor indication of the quantities involved. Analysis of the data gives a precision for each category in the range of ± 10.00. Assume that this precision applies to all categories of users, i.e., industrial, residential, and commercial institutional.

3.2.8 Open Burning

On-site burning refers to the unconfined burning of waste such as leaves, landscape refuse, or other rubbish.

Factors for per-capita generation rate were also derived from the 1968 National Survey of Community Solid Waste Practices[16,17]. Again, determination of the quantity of waste based on this survey is very imprecise. Based on the data examined for on-site incineration, a precision of ± 10.00 is estimated for residential, commercial institutional, and industrial sources of open burning.

3.2.9 Measured Vehicle Miles

Entries are made in these fields of the NEDS form only if a transportation study is available giving the measured vehicle miles traveled. The vehicle miles are categorized by roadway types based on average speeds. Since the data for all roadway types are from the same source, the data for each type should have the same precision. The Bureau of the Census reports that data gathered in the Census of Transportation has a standard deviation of 3.2 percent.

Assume that all transportation studies are as precise as the Census of Transportation. On the basis of Bureau of the Census data, precisions of values for measured vehicle miles on all types of roadways (limited access, rural, suburban, urban) is ± 3.2 percent.

3.2.10 Gasoline Fuel

Three methods are used in calculating consumption of gasoline by on-highway vehicles. Since two of the three methods are interrelated, consider only two methods for calculation of precisions. Method 1 is applied only when there is available a transportation study that provides measured vehicle miles. The study should classify mileage by light- and heavy-duty gasoline vehicles and by heavy-duty diesel vehicles. Method 2 involves obtaining the total statewide gasoline sales from Highway Statistics[18] and apportioning values to counties on the basis of population.

Off-highway gasoline usage is calculated by applying a factor for annual consumption by farm tractors along with a population-based factor to include other off-highway sources.

3.2.10.1 Light-Duty Vehicle - In Method 1 the value for total light-duty vehicle miles is divided by 13.6 miles per gallon[19] to obtain total volume of gasoline consumed by light-duty vehicles. Both factors are obtained from transportation studies and each should have a precision of ± 0.032 (see Section 3.2.9). The overall precision is then:

$$P_o^2 = P_1^2 + P_2^2$$

$$P_o^2 = (0.032)^2 + (0.032)^2$$

$$P_o^2 = 0.002048$$

$$P_o = \pm 0.0453$$

Method 2 involves obtaining the statewide sales of gasoline for highway use, apportioning the gasoline to counties on the basis of the ratio of county service station sales to state service station sales, calculating total gasoline vehicle miles traveled (VMT) by assuming an average 12.2 miles per gallon, assuming that light-duty vehicles account for 89 percent of the total VMT, and assuming that light-duty vehicles obtain 13.6 miles per gallon to obtain gallons consumed by light-duty vehicles. The precision of each factor employed must be calculated to obtain the overall precision.

Published gasoline sales totals by state - This figure is obtained from Highway Statistics.[18] It is compiled from reports by state tax departments and should be a precise figure since tax records are precise.

County service station sales and state service station sales - These figures are obtained from the 1968 Census of Business.[20] The Bureau of Census reports that 80 percent of all stations were canvassed by mail and data for the remaining were obtained by consulting records of the IRS and Social Security Administration. Assuming that the records are accurate, there should be no imprecision other than that introduced by rounding off to the nearest $1,000. Considering the magnitude of sales at service stations, an error of ± $1,000 is insignificant. Therefore consider the sales totals as precise numbers.

12.2 miles per gallon average for all vehicles - This figure, obtained from Highway Statistics,[18] represents the total vehicle miles in the nation divided by the total gasoline consumed. The total VMT is precise within ± 3.2 percent, and the value for gasoline consumed is a precise number. Therefore, the result is also precise within ± 0.032.

89 percent of total vehicle miles are contributed by light-duty vehicles - This figure is obtained from Highway Statistics[18] by finding the ratio of light-duty vehicle miles to heavy-duty vehicle miles. Since each value has a precision of 3.2 percent, the overall precision is determined as follows:

$$P_o^2 = P_1^2 + P_2^2$$

$$P_o = \sqrt{P_1^2 + P_2^2}$$

$$P_o = \sqrt{2(.032)^2}$$

$$P_o = \pm 0.045$$

13.6 miles per gallon average for light-duty vehicles - This value, also from Highway Statistics,[18] is obtained by dividing the total light-duty VMT by the gasoline consumed by light-duty vehicles. Since the same precisions are involved as before, the precision of this value is also ± 0.032.

Overall precision - Multiplying precisions of the five factors just calculated gives the overall precision of the value for off-highway gasoline consumption as obtained by Method 2:

$$P_o = \left[(0)^2 + (0.032)^2 + (0.032)^2 + (0.045)^2 + (0.032)^2\right]^{1/2}$$

$$P_o = [0.005097]^{1/2}$$

$$P_o = \pm 0.071$$

3.2.10.2 Heavy Vehicle - The methods for determining gasoline consumption by heavy vehicles are exactly the same as those for light vehicles. The values of the factors change slightly, but the sources are the same and the precisions are the same. For Method 1, with values obtained from a transportation study, the precision is ± 0.045; for Method 2, which involves apportioning, the precision is ± 0.071

3.2.10.3 Off-Highway - The total off-highway consumption of gasoline is the sum of that used by farm tractors and the amount consumed by other miscellaneous off-highway sources.

Gasoline usage by farm tractors - The total gasoline used by farm tractors is obtained by finding the total number of farm tractors in a county in the Census of Agriculture,[23] assuming that 60 percent are gasoline powered, and applying a factor of 1,000 gallons per tractor per year. Assuming that all these factors are derived from Department of Agriculture figures, and that only counties with 100 or more farms are significant, Table C of the Census of Agriculture[23] may be used to estimate precisions. Using the Table's levels of reliability for fuels and machinery, the precisions for both the fuel consumption factor and the percentage of tractors powered by gasoline are ± 0.10 and the precision of the number of tractors is ± 0.042. The overall precision is then:

$$P_o = \sqrt{P_1^2 + P_2^2 + P_3^2}$$

$$P_o = \sqrt{2(0.10)^2 + (0.042)^2}$$

$$P_o = \pm\ 0.148$$

Miscellaneous off-highway gasoline consumption - This figure is obtained by using a consumption factor of 13 gallons per capita-year and multiplying by the county population. APTD-1137[7] gives no reference for the factor of 13 gallons per capita-year; therefore we assume that the factor is significant only to the nearest ten. This would give a standard error of ± 5 or a precision of ± 0.385. Since the county population is a precise figure, the precision is ± 0.385.

Overall precision - The total off-highway gasoline consumption is the sum of farm tractor usage and miscellaneous usage. Therefore the overall precision is as follows:

$$T = F + M$$

where T = total off-highway gasoline consumption

F = gasoline consumed by farm tractors

M = gasoline consumed by miscellaneous off-highway sources

$$\frac{\text{Var }(T)}{T^2} = \frac{\text{Var }(F + M)}{(F + M)^2}$$

$$\frac{\text{Var }(T)}{T^2} = \frac{\text{Var } F + \text{Var } M}{(F + M)^2}$$

$$\sigma(F) = 0.148\ F$$

$$\sigma(M) = 0.385\ M$$

$$\text{Var }(F) = 0.022\ F^2$$

$$\text{Var }(M) = 0.148\ M^2$$

$$\frac{\text{Var }(T)}{T^2} = \frac{0.022\ F^2 + 0.148\ M^2}{F^2 + 2\ FM + M^2}$$

but $M = 13 \times \text{population } (P)$

and $F = T - M$

therefore $$\frac{\text{Var }(T)}{T^2} = \frac{0.022\ (T - 13P)^2 + 0.148\ (13P)^2}{(T - 13P)^2 + 2\ (13P)(T - 13P) + (13P)^2}$$

$$\frac{\text{Var }(T)}{T^2} = \frac{0.022T^2 - 0.572\ TP + 28.730P^2}{T^2}$$

$$\frac{\sigma(T)}{T} = \left[\frac{\text{Var }(T)}{T^2}\right]^{1/2}$$

$$\text{precision} = \frac{\sigma\ (T)}{T} = \frac{\left[0.022T^2 = 0.572TP + 28.73P^2\right]^{1/2}}{T}$$

3.2.11 Diesel Fuel

This category includes on-highway heavy vehicle use, off-highway use by miscellaneous sources, and rail locomotive use. The various methods used for calculating each case are explained in the following sections.

3.2.11.1 Heavy Vehicle - Methods of calculation are the same as those for calculating gasoline consumption. The first method involves dividing the measured vehicle miles traveled by diesel-powered vehicles by a factor of 5.1 miles per gallon. Both figures are obtained from transportation studies and should have the precision indicated earlier, 0.032. The overall precision is then:

$$P_o^2 = P_1^2 + P_2^2$$

$$P_o^2 = (0.032)^2 + (0.032)^2$$

$$P_o = \pm 0.045$$

The second method involves apportionment of statewide diesel fuel sales to counties on the basis of service station sales.

Statewide diesel fuel sales - This figure is given as "on-highway use of special fuels" in Highway Statistics.[18] It is obtained from data reported by state tax agencies and should be a precise figure.

County service station sales and state service station sales - These figures for sales of diesel fuel are from 1968 Census of Business and are precise numbers.

Overall precision - The factors used in calculating diesel fuel use are precise, but the coding form requires rounding off to the nearest thousand gallons. The precision is then:

$$P = \frac{\pm 0.5}{\text{No. in field}}$$

3.2.11.2 Off-highway - Off-highway diesel fuel consumption is the sum of that used by farm tractors, construction equipment, and other miscellaneous sources.

Diesel fuel usage by farm tractors - The method described for calculation of gasoline usage by tractors applies to calculating diesel fuel usage except that 35 percent of the tractors are assumed to be diesel-powered. The same precisions apply.

$P = \pm 0.148$

Diesel fuel usage by construction equipment - The value for diesel fuel usage by construction equipment is the product of the number of non-building construction employees in the county and a factor of 5,000 gallons per employee-year. The number of non-building construction employees, reported in County Business Patterns[24] is obtained by consulting data from the Social Security Administration and, if needed, by a special multiunit survey. It should be a precise number. The fuel consumption figure should be precise within the limits of significant figures. Precision is then $\frac{+500}{5000}$ or ± 0.10.

Diesel fuel usage by miscellaneous sources - This figure is calculated by applying a factor of 7.4 gallons per capita annually. Since no source is listed for the factor, assume that it is significant only to the nearest unit. Since population is a precise figur the precision equals $\frac{0.5}{7.4}$ or ± 0.07.

Overall precision - It is difficult to determine a precision for all cases without deriving an equation in terms of factors that do not appear on the NEDS area source coding form. Therefore, assume that the precision applying to a median case applies to all cases. The median value for diesel fuel consumed by farm tractors is 792,050 gallons. The median value for diesel fuel consumed by construction equipment is 970,000 gallons, based on 194 non-building construction workers per county. The median value for diesel fuel consumption by other miscellaneous sources is 105,235 gallons gased on a county population of 14,221.

precision median =

$$\left[\frac{(0.148 \times 792{,}050)^2 + (0.1 \times 970{,}000)^2 + (0.07 \times 105{,}235)^2}{(79{,}250 + 970{,}000 + 105{,}235)^2}\right]^{1/2}$$

$$= \pm\ 0.082$$

3.2.11.3 Rail Locomotive - Sales of fuel oil to railroads by state are given in Reference 12, Table 10. County fuel totals are obtained by apportionment on the basis of miles of track per county.

The Bureau of Mines totals may be considered precise within the reported units of 1,000 barrels. Assuming that the median value of 1,231,000 barrels applies to all cases gives a precision of $\frac{500}{1{,}231{,}000}$ or $\pm\ 0.4 \times 10^{-3}$.

Values for miles of track per county are obtained from detailed state maps or may be supplied by the railroads. Assuming that the figure obtained is precise within 10 percent gives an overall precision as follows:

$$P_o{}^2 = (0.10)^2 + (0.4 \times 10^{-3})^2$$

$$P_o{}^2 = 0.010 + 1.6 \times 10^{-7}$$

$$P_o = \pm\ 0.10$$

3.2.12 Aircraft

This category includes all aircraft operations except operations on dirt airstrips. The required values for landing and takeoff (LTO) cycles are obtained from three Federal Aviation Administration (FAA) publications,[25-27] which report the number of "operations" performed by civil, commercial, and military aircraft at all FAA-regulated airports and military airfields. The number of "operations" is divided by 2 to obtain the number of LTO cycles.

3.2.12.1 Military Aircraft - The exact number of operations performed by military aircraft is reported in Military Air Traffic Activity Report[26] and FAA Air Traffic Activity[25]. Therefore, the LTO cycles may be determined precisely. The units of the NEDS form field limit precision, in that the figure must be reported to the nearest 100. Precision is then equal to $\frac{\pm 50}{\text{No. LTO cycles}}$.

3.2.12.2 Civil Aircraft - Civil aircraft operations are also enumerated in FAA Air Traffic Activity[25] and Military Air Traffic Activity Report.[26] Since these reports do not include operations at non-FAA-regulated airfields, figures for these operations must be obtained from the appropriate airfield officials, who should provide an exact figure. Therefore, precision of the number of LTO cycles is limited only by rounding to the nearest 10 as required on the NEDS coding form. The precision will be $\frac{\pm 5}{\text{No. of LTO cycles}}$.

3.2.12.3 Commercial aircraft - The number of LTO cycles for commercial aircraft is detemrined in exactly the same manner as that for civil aircraft and has the same precision, which is $\frac{\pm 5}{\text{No. of LTO cycles}}$.

3.2.13 Vessels

This category, which includes vessels and small craft, is sub-categorized according to type of fuel.

3.2.13.1 Anthracite Coal - No reliable method for estimating emissions from these vessels on a local basis is currently known, because only nationwide fuel totals are available.[11]

Thus information on local fuel consumption can be obtained only from estimates made by port authorities or ship operators.

Anthracite coal usage should be assigned to counties with major ports, according to tonnage handled in the ports. These data are available from Waterborne Commerce of the United States,[28] published by the U.S. Army Corps of Engineers.

The nationwide totals are reported to the nearest thousand tons. The number should be precise within this limitation; for 1969 the precision is $\frac{500}{17,000}$ or 0.03.

Waterborne Commerce of the United States reports the tonnage handled in the ports to the nearest ton. Since all ships are required by law to report their tonnage, this should be a precise figure. The overall precision of the value for anthracite coal consumption by vessels is then ± 0.03.

3.2.13.2 Diesel Oil - Detailed apportioning methods for determining fuel oil consumption by vessels are given in APTD-1135.[7] Assume that all data from Waterborne Commerce of the United States are precise.

In-port fuel consumption - The number of vessels entering a port, obtained from Reference 28, is a precise number. Assume that each vessel spends 3 days in port, and estimate that this figure is precise within 1/2 day or $\frac{0.5}{3}$ = 0.167. The vessel-days in port must be distributed between ships using distillate (diesel) fuel and ships using residual fuel. This is accomplished by using the ratio of distillate oil vessel-days to residual oil vessel-days. First, obtain the number of barrels of each fuel consumed in the state from Reference 12. Convert to vessel-days by assuming that each vessel consumes 660 gal/day of diesel fuel and 1900 gal/day of residual oil. Assuming that these figures are precise within their significant figures gives precision of the diesel fuel factor equal to $\frac{5}{660}$ or ± 0.008 and precision of the residual fuel factor equal to $\frac{50}{1900}$ or ± 0.026. Using median values for total statewide fuel oil consumption by vessels, with a standard deviation of ± 21,000 gallons gives the following precision:

distillate oil - 8,484,000 gallons

residual oil - 7,854,000 gallons

$$\text{distillate-oil vessel-days} = \frac{8{,}484{,}000}{660} = 12{,}855$$

$$\text{precision} = \left[\left(\frac{21{,}000}{8{,}484{,}000}\right)^2 + (0.008)^2\right]^{1/2}$$

$$= \pm\ 0.009$$

$$\text{residual-oil vessel-days} = \frac{7{,}854{,}000}{1{,}900} = 4{,}134$$

$$\text{precision} = \left[\left(\frac{21{,}000}{7{,}854{,}000}\right)^2 + (0.026)^2\right]^{1/2}$$

$$= \pm\ 0.061$$

$$\text{total vessel-days} = 12{,}855 + 4{,}134$$

$$= 16{,}989$$

$$\text{precision} = \left[\frac{(0.009 \times 12{,}855)^2 + (0.061 \times 4{,}134)^2}{(16{,}989)^2}\right]^{1/2}$$

$$= \pm\ 0.02$$

$$\text{percent diesel-oil days} = \frac{12{,}855}{16{,}989}$$

$$\text{precision} = \left[(0.009)^2 + (0.02)^2\right]^{1/2}$$

$$= \pm\ 0.022$$

total diesel-oil days = percent diesel days x number of vessels x 3 days/vessel

$$\text{precision} = \left[(0.022)^2 + 0^2 + (0.167)^2\right]^{1/2}$$

$$= \pm\ 0.009$$

$$\text{residual-oil vessel-days} = \frac{7{,}854{,}000}{1{,}900} = 4{,}134$$

$$\text{precision} = \left[\left(\frac{21{,}000}{7{,}854{,}000}\right)^2 + (0.026)^2\right]^{1/2}$$

$$= \pm\ 0.061$$

$$\text{total vessel-days} = 12{,}855 + 4{,}134$$

$$= 16{,}989$$

$$\text{precision} = \left[\frac{(0.009 \times 12{,}855)^2 + (0.061 \times 4{,}134)^2}{(16{,}989)^2}\right]^{1/2}$$

$$= \pm\ 0.02$$

$$\text{percent diesel-oil days} = \frac{12{,}855}{16{,}989}$$

$$\text{precision} = \left[(0.009)^2 + (0.02)^2\right]^{1/2}$$

$$= \pm\ 0.022$$

total diesel-oil days = percent diesel-oil days x number of vessels x 3 days/vessel

$$\text{precision} = \left[(0.022)^2 + 0^2 + (0.167)^2\right]^{1/2}$$

$$= \pm\ 0.17$$

diesel oil consumption = total diesel-oil days x 660 gallons per day

$$\text{precision} = \left[(0.17)^2 + (0.008)^2\ {}^{1/2}\right]$$

$$= \pm\ 0.17$$

Underway fuel consumption - Underway diesel fuel consumption is assumed to be the difference between the total distillate oil used by vessels (Reference 12), and the total distillate fuel consumed in-port. Using median values, the in-port consumption of distillate is 4,437,668 gallons out of a total of 8,484,000 gallons. Precision of underway diesel fuel consumption is then:

$$\text{precision} \left[\frac{(0.17\times 4{,}437{,}668)^2 + (21{,}000)^2}{(8{,}484{,}000 - 4{,}437{,}668)^2}\right]^{1/2}$$

$$\text{precision} = \pm 0.187$$

Overall precision - Precision of the value for total diesel fuel usage by vessels equals precisions of the in-port consumption value plus precision of the underway consumption value. Based on median values:

$$\text{precision} = \left[\frac{(0.17 \times 4{,}437{,}668)^2 + (0.187 \times 4{,}046{,}332)^2}{8{,}484{,}000^2}\right]^{1/2}$$

$$\text{precision} - \pm 0.13$$

3.2.13.3 Residual oil - In-port residual oil consumption is calculated in the same manner as for diesel fuel. From the preceding section, precision of residual-oil vessel-days equals ± 0.061, precision of total vessel-days equals ± 0.02, and precision of the residual fuel factor equals ± 0.026.

$$\text{precision} = \left[(0.061)^2 + (0.02)^2\right]^{1/2}$$
$$= \pm 0.064$$

total residual-oil days = percent residual-oil days x number of vessels x 3 days/vessel

$$\text{precision} = \left[(0.064)^2 + 0^2 + (0.167)^2\right]^{1/2}$$
$$= \pm 0.018$$

residual oil consumption = total residual-oil days x 1900 gallons/day

$$\text{precision} = \left[(0.18)^2 + (0.026)^2\right]^{1/2}$$
$$= \pm 0.18$$

3.2.13.4 Gasoline - This category includes craft operated by inboard, outboard, or inboard-outboard motors on lakes and rivers. Gasoline consumption by vessels can be estimated by using a factor of 160 gallons of gasoline per boat registration per year. This factor was derived from information on average annual operating hours, average horsepower per vessel, and average fuel consumption per horsepower-hour of operation. The estimate also approximately accounts for any non-motorized boats that may be included in the state total of registrations and for boats with small outboard motors that may not be registered. Boat registration data should be obtained from the appropriate state agency, such as the State Department of Recreation of the Fish and Game Department.

The total gasoline consumption predicted by use of the state total of boat registrations should be apportioned to counties on the basis of inland water surface area. County inland water areas may be determined from the Bureau of the Census' Area Measurement Reports.[29]

The factor of 160 gallons per boat registration should be a good estimate of gasoline consumption. Assuming that it is precise within 25 gallons for each county, the precision is $\frac{25}{160}$ or ± 0.156.

The number of boat registrations is a precise number.

The surface area of water in a state is reported in square miles. The Bureau of Census reports that the figures are accurate within 1 percent. Based on median values for county and state, precision for the state figure is 0.01, but the county figure is less precise because of rounding off: P equals $\frac{0.5}{21.9}$ or 0.023.

Based on median values, the overall precision of a value for gasoline consumption by vessels is:

$$P_o = \left[(0.156)^2 + (0.01)^2 + (0.023)^2\right]^{1/2}$$

$$P_o = \pm\ 0.158$$

3.2.14 Evaporation

This category includes losses of hydrocarbons and other organic compounds by evaporation at sources not considered as point sources. These sources include gasoline-handling, dry cleaning, surface coating, and miscellaneous solvent-use operations.

3.2.14.1 Solvent-Purchased Methods of Determination - Methods for determining evaporation losses as a function of solvent purchases entail (1) a questionnaire survey of all solvent users, or (2) the assumption that solvent use is proportional to population and is dependent on the population density.

Questionnaire survey of all solvent users - A survey is the best and most accurate method of determining solvent use. Most companies maintain records of purchase orders that show solvent use. Precision depends on the significant figures reported on the questionnaires. Although this figure varies among the reporting companies, one can assume that it is reported within ± 50 tons. Precision is then:

$$P = \pm \frac{50}{\text{No. in field}}$$

Assume solvent use is proportional to population and dependent on population density - This method is used for most counties, since surveys require considerable time and effort.

For dry cleaning operations use factors of 2.0 solvent per person per year in moderate climates and 2.7 lb per person per year for colder climates.

For other solvent losses apply values from the following table:

County population	Solvent loss, lb per capita per year
<100,000	3
100,000 to 500,000	8
500,000 to 1,000,000	18
>1,000,000	28

Since APTD-1135 does not cite references from which these factors for evaporation losses were obtained, the best possible precision value is based on an engineering estimate.

Losses from dry cleaning operations are based on population, climate, and factors for dry cleaning loss per person. Since the population value is a precise figure, all imprecision arises from the factors dependent on climate; that is, 2.0 and 2.7 lb/person for moderate and cold climates, respectively. Assuming that the factors are correct, the usage should cover a range from 2.0 to 2.7, since climate does not change abruptly from moderate to cold. If errors are randomly distributed, the range 2.0 to 2.7 should contain 99 percent of the values. Assuming the range is 3 standard deviations, T = ± 0.2333. Related to a median value of 2.35 for the use factor, the precision equals ± 10 percent.

Other solvent losses are also considered in this category. Since the population figure is precise, any imprecision results from errors in the solvent-use factors. Estimating the error in each factor as ± 5 and using the median value for each range, precision for each range is determined:

T = total solvent loss

D = dry cleaning loss

S = miscellaneous solvent loss

X = population

$\sigma(D) = 0.1\ (2.35)(X)$

$\sigma(S) = 5\ (X)$

$\mathrm{Var}\ (D) = [\sigma\ (D)]^2 = 0.055225\ X^2$

$\mathrm{Var}\ (S) = [\sigma\ (S)]^2 = 25\ X^2$

Since $T = D + S$

$$\frac{\mathrm{Var}(T)}{T^2} = \frac{\mathrm{Var}(D) + \mathrm{Var}(S)}{(D + S)^2}$$

$\mathrm{Var}(T) = 25.055225\ X^2$

$\sigma(T) = \sqrt{25.055225\ X^2}$

$\sigma(T) = 5.00552\ X$

Range	T	$P = \frac{\sigma(T)}{T}$
0 - 100,000 (X = 50,000)	5.35 X	± 0.936
100,000-500,000 (X = 300,000)	10.35 X	± 0.484
500,000-1,000,000 (X = 750,000)	20.35 X	± 0.246
>1,000,000 (X = 1,500,000)	30.35 X	± 0.165

3.2.14.2 Gasoline Handling - This category includes only evaporative losses that occur as a result of service station operations. Among three possible data collection methods, the most common method involves totaling the entries for light vehicle, heavy vehicle, and off-highway consumption of gasoline. Precision then depends on the precisions of these entries. For most counties, off-highway consumption is negligible in comparison with consumption by light and heavy vehicles. Assume then that precision depends only on the precisions of values for light and heavy vehicle consumption:

$$T = L + H$$

where T = gasoline marketed at service stations

L = light-vehicle gasoline usage

H = heavy-vehicle gasoline usage

$$\frac{\text{Var }(T)}{T^2} = \frac{\text{Var }(L) + \text{Var }(H)}{(L + H)^2}$$

but $T^2 = (L + H)^2$

therefore

$$\frac{\text{Var }(T)}{T^2} = \frac{\text{Var }(L) + \text{Var }(H)}{T^2}$$

$$\mathrm{Var}\ (L) = [\sigma(L)]^2 = (0.071L)^2 \text{ (per Section 3.2.10.1)}$$

$$\mathrm{Var}\ (H) = [\sigma(H)]^2 = (0.072H)^2 \text{ (per Section 3.2.10.2)}$$

$$\frac{\mathrm{Var}\ (T)}{T^2} = \frac{0.0050L^2 + 0.0052H^2}{T^2}$$

Assume that light vehicles using 13.6 miles per gallon account for 89 percent of the VMT and heavy vehicles using 8.4 miles per gallon account for 11 percent; then

$$H = 0.2L$$

$$\frac{\mathrm{Var}\ (T)}{T^2} = \frac{0.0050L^2 + 0.0052(0.2L)^2}{T^2}$$

$$\frac{\mathrm{Var}\ (T)}{T^2} = \frac{0.00521L^2}{T^2}$$

$$\frac{\sigma\ (T)}{T} = \frac{0.072L}{T}$$

but $T = 1.2L$

$$\frac{\sigma\ (T)}{T} = 0.060$$

precision = $\pm$ 0.060

3.2.15 Fugitive Dust Sources

This section deals with precision of values reported for emissions of fugitive dust from sources that include dirt roads, dirt airstrips, construction sites, rock handling sites, and several miscellaneous sources.

3.2.15.1 Dirt Roads - The value for vehicle miles of travel on dirt roads is obtained by using the figure given by the State

Highway Department for total mileage of dirt roads in each county and by estimating the amount of traffic.

The State Highway Department usually can supply a figure for the mileage of dirt roads that is precise within the nearest mile. Estimating at least 10 miles of dirt road per county as a median value gives a precision of $\frac{0.5}{10}$ or ± 0.05.

Estimating the number of vehicles that travel over dirt roads introduces more imprecision. If at least some data are available on which to base an estimate, the figure for number of vehicles should be precise within 50 percent.

The overall precision is then:

$$P_o^2 = (0.5)^2 + (0.05)^2$$

$$P_o = \pm 0.502$$

3.2.15.2 Dirt Airstrips - Airstrip operators who are contacted for the required information should be able to supply the exact number of LTO cycles performed on the airstrip.

$$\text{Precision} = \pm 0$$

3.2.15.3 Construction Sites - This category includes construction sites and other areas subject to severe soil erosion. These areas are estimated by the appropriate state officials, presumably to the nearest 5000 acres with precision.

$$\text{precision} = \frac{\pm 5000}{\text{No. in field}}$$

3.2.15.4 Rock Handling and Storage - These are sources too small to qualify as point sources. For rock-handling operations, state offices should have registration forms giving thruput values. Each source should report thruput precisely at least to the nearest thousand tons. The precision of the area source totals then depends on the units reported. The figure is rounded to the nearest thousand tons, giving precision equal to:

$$P = \frac{\pm 0.5}{\text{No. in field}}$$

3.2.16 Miscellaneous Sources

Sources in this category are characterized by intermittent emissions of fugitive dust. Techniques for collection of data for estimating emissions generally do not yield precise values.

3.2.16.1 Forest Fires -

Area - Data on areas involved in forest fires are obtained from the U.S. Forest Service or from state forest agencies, which report acreage to the nearest acre. It is doubtful that these acres are measured precisely, without the use of aerial photography, which yields the most precise value for affected acreage but is not used by most state forest agencies. Other methods of measurement involve estimation of the extent of the fire by personnel using maps or other indicators to determine dimensions of the burned area. These estimates will produce a precise figure if the outer limits of the burned area are determined carefully. Assuming this is the case, the area value should be precise within ± 0.05.

Quantity (tons/acre) - A value for tons of wood per acre is also obtained from the U.S. or state forestry services. If data are not available, use 40 tons/acre for heavily forested areas or 20 tons/acre for thinly forested areas. Since no data are at hand on which to base a precision value, assume that the density of forestation is precise within ± 0.15.

3.2.16.2 Slash Burning -

Area - This category includes areas of slash burning and agricultural field burning. Values for slash burning areas can be obtained from the U.S. Forest Service or the state Forestry Department.

Values for agricultural field burning area must be estimated by the state Agricultural Department. Precision values vary from county to county dependent on: 1) whether burning is extensive in the locale; 2) significant figures reported; 3) sources of the data. The best precision estimate must be based on several assumptions to be applied to all counties.

Where the total slash burning area in the county is less than 100 acres, assume the number is precise within ± 50 percent. Where the total burning area is 100 acres or greater, assume the figure is precise within 50 acres.

$$\text{precision} = \frac{\pm 50}{\text{No. in field}}$$

Quantity (tons/acre) - The quantity of timber that is slash-burned should be obtainable from the U.S. Forest Service or the state Forestry Department. If it is not, use 75 tons/acre.

For agricultural field burning area use a state Agricultural Department estimate or a factor of 2.5 tons/acre.

For counties in which both slash and agricultural field burning are practiced, use a weighted average.

Again, a precision value applicable to all counties is determined on the basis of these assumptions:

1. Assume that all counties with a figure in this field have both slash and agricultural field burning.
2. Assume the same precision for values obtained for slash and agricultural field burning: ± 0.25.

3.2.16.3 Frost Control

Number of orchard heaters - County or state Agricultural Departments probably can indicate the number of orchard heaters in use. Local orchard operators can confirm this information or give a better figure. Assuming that orchard operators are willing to supply this information, the figure should be precise within the nearest hundred as reported on the NEDS area source coding form.

$$\text{precision} = \frac{\pm 50}{\text{No. of orchard heaters}}$$

Firing days per year - Determine this figure by a representative sampling of orchard grove operators. Assume that all heaters in a county are fired for the same amount of time and that the number reported is precise at least within 10 days:

$$\text{precision} = \frac{\pm 5.0}{\text{days per year}}$$

3.2.16.4 Structure fires - Local fire control agencies can supply the number of structural fires. Assume that the number of unrecorded or unreported fires is 5 or less: precision is then equal to $\frac{\pm 5.0}{\text{No. of fires}}$.

3.2.16.5 Coal refuse burning - Coal refuse piles consist of below-standard coal that has been discarded. Ignition of these piles and smoldering cause significant air pollution.

Size of bank - Three dimensions of the bank are estimated to obtain the volume. The area factor should be precise with 10 percent, since maps can usually give detailed outlines of the bank. Estimation of depth of the bank introduces more error, since depths vary according to the terrain on which burning occurs. Estimate that the depth factor is precise within 25 percent. Precision is then calculated as follows:

$$P^2 = (0.10)^2 + (0.25)^2$$

$$P = \pm 0.27$$

Number of burning coal refuse piles - The state air pollution control agency should provide an exact number of coal refuse burning operations:

$$\text{precision} = \pm 0$$

3.3 PRECISION OF AUTOMOTIVE EMISSION FACTORS

As with emissions from point sources and from other area sources, we consider emissions from automotive vehicles in terms of priority and non-priority pollutants. We did not make a detailed study and determination of precision of emission factors for non-priority pollutants from motor vehicles. Instead, we apply to this category the average precisions calculated for emission factors for non-priority pollutants from point sources.

These precision values were calculated in Section 2.1.3 and are summarized below:

	Part.	SO_x	HC	CO
Average precision	0.211	0.146	0.237	0.357

Precisions of all automotive emission factors are summarized in Table 3.4.

Table 3.4. PRECISIONS OF MOTOR VEHICLE EMISSION FACTORS

Road Type	Vehicle classification	Precision				
		Part.	SO_x	NO_x	HC	CO
Urban	LDG	0.211	0.146	0.028	0.025	0.036
	HDG	0.211	0.146	0.028	0.019	0.034
	HDD	0.211	0.146	0.035	0.237	0.357
Suburban	LDG	0.211	0.146	0.028	0.024	0.036
	HDG	0.211	0.146	0.028	0.019	0.034
	HDD	0.211	0.146	0.035	0.237	0.357
Rural	LDG	0.211	0.146	0.028	0.024	0.036
	HDG	0.211	0.146	0.028	0.018	0.035
	HDD	0.211	0.146	0.035	0.237	0.357
Limited Access	LDG	0.211	0.146	0.028	0.023	0.036
	HDG	0.211	0.146	0.028	0.018	0.035
	HDD	0.211	0.146	0.035	0.237	0.357

The balance of this section is devoted to calculations of precisions of the priority pollutant emission factors as they are related to several categories of motor vehicles. The priority pollutants for light-duty and heavy-duty gasoline-powered highway vehicles are NO_x, HC, and CO. For heavy-duty, diesel-powered highway vehicles the priority pollutant is NO_x.

Because it is not possible to determine the exact process by which the emission factors were calculated for use in the NEDS program, several assumptions are necessary. Using the data and procedure outlined in AP-42, we assume that the 1-year-old vehicles in the population are of the 1973 model year and apply the emission rates and deterioration factors designated for low-altitude areas (excluding California).

3.3.1 Light-Duty, Gasoline-Powered Highway Vehicles

Emission factors for light-duty, gasoline-powered highway vehicles (LDG) are calculated by the method presented in Section 3.1.2 of AP-42, in which LDG exhaust emission factors for NO_x, HC, and CO are expressed mathematically as:

$$e_{np} = \sum_{i=n-12}^{n+1} c_i d_i m_i s_i$$

where: e_{np} = Emission factor in grams per vehicle mile for calendar year (n), and pollutant (p)

c_i = The 1975 Federal test procedure emission rate for pollutant (p) in g/mi for the i^{th} model year at low mileage

d_i = The controlled vehicle pollutant (p) emission deterioration factor for the i^{th} model year at calendar year (n)

m_i = The weighted annual travel of the i^{th} model year during calendar year (n). The determination of this variable involves the use of the vehicle model year distribution

s_i = The weighted speed adjustment factor for the i^{th} model year vehicles

The factor for evaporative and crankcase emissions of HC is calculated and added to the exhaust HC emission factor to give the total HC emissions from LDG's. The following expression for calculating evaporative and crankcase HC emissions is also from Section 3.1.2 of AP-42:

$$f_n = \sum_{i=n-12}^{n+1} h_i m_i$$

where: f_n = The combined evaporative and crankcase hydrocarbon emission factor for calendar year (n)

h_i = The combined evaporative and crankcase emission rate for the i^{th} model year

m_i = The weighted annual travel of the i^{th} model year during calendar year (n)

In order to calculate the precision of the emission factor, the precisions of c_i, d_i, m_i, s_i, and h_i must first be determined.

3.3.1.1 Deterioration factor, d_i - Factors to account for deterioration of exhaust control devices were obtained from Table 3.1.2-5 of AP-42. To calculate the precision of the deterioration factors (and also of other terms used to calculate the emission factor) we consulted the references used to develop the factors. A report of the California Air Resources Laboratory[31] is cited with respect to calculation of deterioration factors. This report presents graphs of HC and CO emissions versus mileage for California automobiles of model years 1966 through 1970. Deterioration factors for each model year are calculated by dividing the emissions at a certain vehicle age (as determined by mileage levels) by the emissions at age zero. The relationship between age and mileage[a] is given as:

Vehicle Age (Years)	0	1	2	3	4	5	6
Mileage (thousands of miles)	4.0	17.5	33.6	46.8	58.2	69.9	79.9

In addition to the graphs, the report gives gross regression data by model year and manufacturer at various mileages. These data (value, upper and lower limits) are interpreted to mean that the upper limit minus the value, divided by two equals the standard deviation of the value. We calculated a weighted average of the standard deviation using the weighting factors given in the reference as a basis for the graphs of emissions versus mileage:

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[a] Data obtained from D. Kircher, U.S. EPA, March 9, 1973.

	Fraction of total sales
Chrysler	0.16
Ford	0.34
General Motors	0.50

The weighted standard deviation was then based on this formula:

$$S_{x\text{-mileage}} = \left[(W_c)^2(S_c)^2+(W_f)^2(S_f)^2+(W_g)^2(S_g)^2\ {}^{1/2}\right]$$

where W_c, W_f, and W_g = weighting factors for Chrysler, Ford, and GM, respectively.

S_c, S_f, and S_g = standard deviations for Chrysler, Ford, and GM, respectively.

The variance at X-miles was:

$$\text{Var (X-miles)} = \left[S_x - \text{miles}\right]^2$$

Since the formula for the deterioration factor, d, is

$$d_{(age)} = \frac{\text{Value}_{\text{x-miles}}}{\text{Value}_{4000}}$$

the formula for variance of the deterioration factor, Var(d), is:

$$\text{Var(d)} = (d)^2 \left[\frac{\text{Var}(4000)}{(\text{Value}_{4000})^2} + \frac{\text{Var (x-miles)}}{(\text{Value}_{\text{x-miles}})^2}\right]$$

Table 3.5 summarizes the variance of deterioration factors; Tables 3.6 through 3.11 show the calculations performed for model years 1968 through 1970.

Reference 31 does not provide enough data for calculation of precision of the deterioration factors for NO_x emissions. It presents a graph of 1971 model year vehicle emissions versus mileage, but gives no gross regression data for that graph. EPA used the 1971 California NO_x data in the report in compiling 1973 nationwide (except California) NO_x deterioration factors. We estimated that the average precisions of the HC and CO deterioration factors for 1973 model cars at age 1 year would give

Table 3.5 VARIANCE OF DETERIORATION FACTOR, d_i

Age	Model year	CO			(Exhaust) HC		
		d_i	$\mathrm{Var}(d_i)$	$\frac{\mathrm{Var}(d_i)}{(d_i)^2}$	d_i	$\mathrm{Var}(d_i)$	$\frac{\mathrm{Var}(d_i)}{(d_i)^2}$
1	1973	1.18	0.00309	0.00222	1.05	0.000662	0.00060
2	1972	1.32	0.00517	0.00297	1.10	0.000984	0.00081
3	1971	1.38	0.00617	0.00324	1.13	0.00134	0.00105
4	1970	1.40	0.00633	0.00323	1.15	0.00133	0.00100
5	1969	1.68	0.00220	0.00078	1.23	0.000507	0.00034
6	1968	1.58	0.00153	0.00061	1.28	0.000441	0.00027
7	1967	1.00	0.0	0.0	1.00	0.0	0.0
8	1966	1.00	0.0	0.0	1.00	0.0	0.0
9	1965	1.00	0.0	0.0	1.00	0.0	0.0
10	1964	1.00	0.0	0.0	1.00	0.0	0.0
11	1963	1.00	0.0	0.0	1.00	0.0	0.0
12	1962	1.00	0.0	0.0	1.00	0.0	0.0
≥13	1961 & older	1.00	0.0	0.0	1.00	0.0	0.0

Table 3.6 CALCULATION OF VARIANCE OF DETERIORATION FACTOR: CO, 1970

Vehicle age	Mileage	Chrysler				Ford				GM			
		Value	Upper	d_m	S_c	Value	Upper	d_m	S_f	Value	Upper	d_m	S_g
0	4,000	0.61	0.70	0.09	0.045	0.064	0.70	0.06	0.03	0.79	0.85	0.06	0.03
1	17,500	0.70	0.86	0.16	0.08	0.82	0.92	0.10	0.05	0.89	0.99	0.10	0.05
2	33,600	0.74	0.96	0.22	0.11	0.92	1.05	0.13	0.065	0.93	1.07	0.14	0.07
3	46,800	0.77	1.02	0.25	0.125	0.97	1.12	0.15	0.075	0.96	1.11	0.15	0.075
4	58,200	0.80	1.05	0.25	0.125	1.00	1.16	0.16	0.08	0.99	1.14	0.15	0.075

Vehicle age	S_x	Var(x)	Weighted value	Deterioration factor, d	Var(d)
0	0.020	0.00038	0.72	1.00	0.0
1	0.033	0.00108	0.85	1.18	0.00309
2	0.045	0.00202	0.95	1.32	0.00517
3	0.050	0.00246	0.99	1.38	0.00617
4	0.050	0.00255	1.01	1.40	0.00633

Where: d_m = (Upper - Value) and S_c, S_f, and $S_g = \frac{d_m}{2}$

$\left[\mathrm{Var}(x)\right]^{1/2} = S_x = \left[W_c^2 S_c^2 + W_f^2 S_f^2 + W_g^2 S_g^2\right]^{1/2}$ and $W_c = 0.16$, $W_f = 0.34$, $W_g = 0.50$

$$\mathrm{Var}(d_a) = d_a^2 \left[\frac{\mathrm{Var}(4000)}{(\mathrm{Value}_{4000})^2} + \frac{\mathrm{Var}(m)}{(\mathrm{Value}_m)^2}\right] \quad \text{when} \quad d_a = \frac{\mathrm{WT.\ Value}_m}{\mathrm{WT.\ Value}_{4000}}$$

Table 3.7 CALCULATION OF VARIANCE OF DETERIORATION FACTOR: CO, 1969

Vehicle age	Mileage	Chrysler				Ford				GM			
		Value	Upper	d_m	S_c	Value	Upper	d_m	S_f	Value	Upper	d_m	S_g
0	4,000	0.89	0.97	0.08	0.040	0.70	0.74	0.04	0.02	1.15	1.20	0.05	0.025
5	69,900	1.24	1.41	0.17	0.085	1.07	1.17	0.10	0.05	1.64	1.74	0.10	0.050

Vehicle age	S_x	Var(x)	Weighted value	Deterioration factor, d	Var(d)
0	0.016	0.000243	0.90	1.00	
5	0.033	0.0011	1.51	1.68	0.00220

Where: $d_m = (\text{Upper} - \text{Value})$ and S_c, S_f, and $S_g = \frac{d_m}{2}$

$$\left[\text{Var}(x)\right]^{1/2} = S_x = \left[W_c^2 S_c^2 + W_f^2 S_f^2 + W_g^2 S_g^2\right]^{1/2} \quad \text{and } W_c = 0.16,\ W_f = 0.34,\ W_g = 0.50$$

$$\text{Var}(d_a) = d_a^2 \left[\frac{\text{Var}(4000)}{(\text{Value}_{4000})^2} + \frac{\text{Var}(m)}{(\text{Value}_m)^2}\right] \quad \text{when} \quad d_a = \frac{\text{WT. Value}_m}{\text{WT. Value}_{4000}}$$

Table 3.8 CALCULATION OF VARIANCE OF DETERIORATION FACTOR: CO, 1968

Vehicle age	Mileage	Chrysler				Ford				GM			
		Value	Upper	d_m	S_c	Value	Upper	d_m	S_f	Value	Upper	d_m	S_g
0	4,000	0.99	1.05	0.06	0.03	0.93	0.99	0.06	0.03	1.15	1.20	0.05	0.025
6	79,900	1.42	1.52	0.10	0.05	1.40	1.52	0.12	0.06	1.79	1.87	0.08	0.04

Vehicle age	S_x	Var(x)	Weighted value	Deterioration factor, d	Var(d)
0	0.017	0.000283	1.02		
6	0.030	0.00088	1.61	1.58	0.00153

Where: d_m = (Upper - Value) and S_c, S_f, and $S_g = \frac{d_m}{2}$

$$\left[\mathrm{Var}(x)\right]^{1/2} = S_x = \left[W_c{}^2 S_c{}^2 + W_f{}^2 S_f{}^2 + W_g{}^2 S_g{}^2\right]^{1/2} \quad \text{and } W_c = 0.16,\ W_f = 0.34,\ W_g = 0.50$$

$$\mathrm{Var}(d_a) = d_a{}^2 \left[\frac{\mathrm{Var}(4000)}{(\mathrm{Value}_{4000})^2} + \frac{\mathrm{Var}(m)}{(\mathrm{Value}_m)^2}\right] \quad \text{when} \quad d_a = \frac{\mathrm{WT.\ Value}_m}{\mathrm{WT.\ Value}_{4000}}$$

Table 3.9 . CALCULATION OF VARIANCE OF DETERIORATION FACTOR: HC, 1970

Vehicle age	Mileage	Chrysler				Ford				GM			
		Value	Upper	d_m	S_c	Value	Upper	d_m	S_f	Value	Upper	d_m	S_g
0	4,000	172	183	11	5.5	185	192	8	4.0	171	179	8	4.0
1	17,500	185	202	17	8.5	201	213	12	6.0	200	212	12	6.0
2	33,600	191	214	23	11.5	210	226	16	8.0	214	229	15	7.5
3	46,800	194	220	26	13.0	214	232	18	9.0	221	240	19	9.5
4	58,200	198	225	27	13.5	218	235	17	8.5	226	245	19	9.5

Vehicle age	S_x	Var(x)	Weighted value	Deterioration factor, d	Var(d)
0	2.57	6.62	183		
1	3.87	15.01	193	1.05	0.000662
2	4.98	24.85	201	1.10	0.000984
3	6.02	36.25	206	1.13	0.00134
4	5.96	35.58	210	1.15	0.00133

Where: d_m = (Upper - Value) and S_c, S_f, and $S_g = \frac{d_m}{2}$

$\left[\mathrm{Var}(x)\right]^{1/2} = S_x = \left[W_c{}^2 S_c{}^2 + W_f{}^2 S_f{}^2 + W_g{}^2 S_g{}^2\right]^{1/2}$ and $W_c = 0.16$, $W_f = 0.34$, $W_g = 0.50$

$$\mathrm{Var}(d_a) = d_a{}^2 \left[\frac{\mathrm{Var}(4000)}{(\mathrm{Value}_{4000})^2} + \frac{\mathrm{Var}(m)}{(\mathrm{Value}_m)^2}\right] \quad \text{when} \quad d_a = \frac{\mathrm{WT.\ Value}_m}{\mathrm{WT.\ Value}_{4000}}$$

Table 3.10 CALCULATION OF VARIANCE OF DETERIORATION FACTOR: HC, 1969

Vehicle age	Mileage	Chrysler				Ford				GM			
		Value	Upper	d_m	S_c	Value	Upper	d_m	S_f	Value	Upper	d_m	S_g
0	4,000	244	255	11	5.5	249	257	8	4.0	235	242	7	3.5
5	69,900	322	345	23	11.5	290	305	15	7.5	286	299	13	6.5

Vehicle age	S_x	Var(x)	Weighted value	Deterioration factor, d	Var(d)
0	2.38	5.69	240		
5	4.52	20.5	295	1.23	0.000507

Where: d_m = (Upper - Value) and S_c, S_f, and $S_g = \frac{d_m}{2}$

$\left[\text{Var}(x)\right]^{1/2} = S_x = \left[W_c^2 S_c^2 + W_f^2 S_f^2 + W_g^2 S_g^2\right]^{1/2}$ and $W_c = 0.16$, $W_f = 0.34$, $W_g = 0.50$

$$\text{Var}(d_a) = d_a^2 \left[\frac{\text{Var}(4000)}{(\text{Value}_{4000})^2} + \frac{\text{Var}(m)}{(\text{Value}_m)^2}\right] \quad \text{when} \quad d_a = \frac{\text{WT. Value}_m}{\text{WT. Value}_{4000}}$$

Table 3.11 CALCULATION OF VARIANCE OF DETERIORATION FACTOR: HC, 1968

Vehicle age	Mileage	Chrysler				Ford				GM			
		Value	Upper	d_m	S_c	Value	Upper	d_m	S_f	Value	Upper	d_m	S_g
0	4,000	255	263	8	4.0	270	279	9	4.5	260	268	8	4.0
6	79,000	330	344	14	7.0	337	350	13	6.5	348	360	12	6.0

Vehicle age	S_x	Var(x)	Weighted value	Deterioration factor, d	Var(d)
0	3.00	9.00	260		
6	3.89	15.1	333	1.28	0.000441

Where: d_m = (Upper - Value) and S_c, S_f, and $S_g = \frac{d_m}{2}$

$$\left[\mathrm{Var}(x)\right]^{1/2} = S_x = \left[W_c{}^2 S_c{}^2 + W_f{}^2 S_f{}^2 + W_g{}^2 S_g{}^2\right]^{1/2} \quad \text{and } W_c = 0.16,\ W_f = 0.34,\ W_g = 0.50$$

$$\mathrm{Var}(d_a) = d_a{}^2 \left[\frac{\mathrm{Var}(4000)}{(\mathrm{Value}_{4000})^2} + \frac{\mathrm{Var}(m)}{(\mathrm{Value}_m)^2}\right] \quad \text{when} \quad d_a = \frac{\mathrm{WT.\ Value}_m}{\mathrm{WT.\ Value}_{4000}}$$

a good approximation of the precision of the NO_x deterioration factor for a vehicle of the same model and age. We analyzed data from the Six Cities Report[32] to determine whether a pattern developed among precisions for HC, CO, and NO_x. Since no trend was found, we decided to use the average precision of HC and CO deterioration factors as the precision of the NO_x deterioration factor, as follows:

Age	Model Year	$(\text{Precision})^2 = \frac{\text{Var}(d_i)}{(d_i)^2}$ HC	CO	Ave = NO_x
1	1973	0.00060	0.00222	0.00141

On this basis, the NO_x deterioration factor for 1973 model cars 1 year old is 1.11, and the precision of that factor equals 0.0375.

3.3.1.2 1975 Federal Test Procedure Emission Rate, c_i - Exhaust emission factors at low mileage per model year (c_i) are given in Table 3.1.2-1 of AP-42. These factors were calculated with test data from the Six Cities Report (Reference 32) and the deterioration factors (Reference 31).

The exhaust emission rates for pre-1968 vehicles at low altitudes are the average of test data from pre-1968 model cars in five of the six test cities (excluding Denver). Since these vehicles were not subject to deterioration of exhaust control devices, no deterioration factors were applied to obtain low-mileage emission rates. Hence the variance of the emission rates for pre-1968 model vehicles was calculated from the average standard deviation of all pre-1968 data and the number of observations in the Six Cities Report of the corresponding model year. Tables 3.12 through 3.14 show the variance of the emission rates for pre-1968 automobiles, by pollutant.

The low-mileage HC and CO emission rates for 1968 through 1971 model cars were calculated by dividing emission values for vehicles in the five low-altitude cities by the appropriate deterioration factor. No deterioration factor was applied to NO_x emission rates, since the vehicles had no NO_x controls.

The precision of the emission rates for 1968 through 1971 model cars includes both the precision of the test data from the Six Cities Report and the precision of the deterioration factor used to project low-mileage emissions (except for NO_x). We calculated the precision of the Six Cities Report test data using the standard deviations, S, of the test results. We then calculated the standard deviation of the mean, $S_{\bar{x}}$, by dividing S by the square root of the number of observations, and calculated precision by dividing $S_{\bar{x}}$ by the emission factor. These calculations are summarized in Table 3.15.

Precision of the deterioration factors were calculated according to the procedure described in the preceding section. Calculations of the precisions of deterioration factors not given earlier are shown in Tables 3.16 through 3.19.

Variance of the low-mileage emission rate, c_i, where:

$$c_i = \frac{\text{Six Cities Data}}{\text{Deterioration Factor}}$$

was calculated by the formula:

$$\text{Var}(c_i) = (c_i)^2 \left[\frac{\text{Var (Six Cities)}}{(\text{Value}_{\text{Six Cities}})^2} + \frac{\text{Var }(d_i)}{(d_i)^2}\right]$$

Table 3.12 ANALYSIS OF SIX CITIES DATA: PRE-1968, CO

Average Emission Factor, c_i = 87^a

Average Standard Deviation, S = 40.41^b

Model year	Emission factor, C_i	N	S_x	$Var(C_i)$
1967	87	71	4.796	23.0
1966	87	83	4.436	19.7
1965	87	80	4.518	20.4
1964	87	64	5.051	25.5
1963	87	55	5.449	29.7
1962	87	38	6.556	43.0
1961 & older	87	100	4.041	16.3

Where:

N = Number of test observations at low altitude found in Reference 32 of the corresponding model year.

$$S_{\bar{x}} = \frac{S}{n}$$

$$Var(C_i) = (S_{\bar{x}})^2$$

a) Taken from AP-42 (Reference 30).

b) Calculated from data presented in Reference 32.

Table 3.13 ANALYSIS OF SIX CITIES DATA: PRE-1968, HC

Average Emission Factor, c_i = 8.8[a]

Average Standard Deviation, S = 7.47[b]

Model year	Emission factor, C_i	N	S_x	$Var(C_i)$
1967	8.8	71	0.087	0.786
1966	8.8	83	0.820	0.672
1965	8.8	80	0.835	0.698
1964	8.8	64	0.934	0.872
1963	8.8	55	1.007	1.015
1962	8.8	38	1.212	1.469
1961 & older	8.8	100	0.747	0.558

Where:

N = Number of test observations at low altitude found in Reference 32 of the corresponding model year.

$$S_{\bar{x}} = \frac{S}{n}$$

$$Var(C_i) = (S_{\bar{x}})^2$$

a) Taken from AP-42 (Reference 30).

b) Calculated from data presented in Reference 32.

Table 3.14 ANALYSIS OF SIX CITIES DATA: PRE-1968, NO_x

Average Emission Factor, c_i = 3.6^a

Average Standard Deviation, S = 1.89^b

Model year	Emission factor, C_i	N	S_x	$Var(C_i)$
1967	3.6	71	0.224	0.0503
1966	3.6	83	0.207	0.0430
1965	3.6	80	0.211	0.0447
1964	3.6	64	0.236	0.0558
1963	3.6	55	0.255	0.0650
1962	3.6	38	0.307	0.0940
1961 & older	3.6	100	0.189	0.0357

Where:

N = Number of test observations at low altitude found in Reference 32 of the corresponding model year.

$S_{\bar{x}} = \frac{S}{n}$

$Var(C_i) = (S_{\bar{x}})^2$

a) Taken from AP-42 (Reference 30).

b) Calculated from data presented in Reference 32.

Table 3.15 ANALYSIS OF SIX CITIES DATA, 1968-1971

Year	HC		CO		NO_x	
	$\sigma\bar{x}=\frac{\sigma}{\sqrt{n}}$	$\frac{\sigma\bar{x}}{\bar{x}}\left[100\right]=\%$	$\sigma\bar{x}=\frac{\sigma}{\sqrt{n}}$	$\frac{\sigma\bar{x}}{\bar{x}}\left[100\right]=\%$	$\sigma\bar{x}=\frac{\sigma}{\sqrt{n}}$	$\frac{\sigma\bar{x}}{\bar{x}}\left[100\right]=\%$
1971	0.125	4.08	2.436	6.07	0.177	3.68
1970	0.210	5.38	2.660	5.52	0.180	3.56
1969	0.453	8.73	3.289	5.33	0.214	3.92
1968	0.777	13.97	6.298	9.25	0.211	4.86
Pre-1968	0.337	3.92	1.824	2.14	0.0853	2.41

$$c_i = \frac{\text{Six cities test data}}{\text{deterioration factor}}$$

$$\mathrm{Var}(c_i) = (c_i)^2 \left[\frac{(\sigma\bar{x}_{\text{six cities}})^2}{(\bar{x}_{\text{six cities}})^2} + \frac{\mathrm{Var}(d_i)}{(d_i)^2}\right]$$

$$\mathrm{Var}(c_i) = (\sigma\bar{x})^2$$

Table 3.16 CALCULATION OF VARIANCE OF DETERIORATION FACTOR: HC, 1969

Vehicle age	Mileage	Chrysler				Ford				GM			
		Value	Upper	d_m	S_c	Value	Upper	d_m	S_f	Value	Upper	d_m	S_g
0	4,000	244	255	11	5.5	249	257	8	4.0	235	242	7	3.5
3	46,800	310	332	22	11.0	279	294	15	7.5	275	287	12	6.0

Vehicle age	S_x	Var(x)	Weighted value	Deterioration factor, d	Var(d)
0	2.38	5.69	240		
3	4.31	18.6	283	1.18	0.000461

Where: d_m = (Upper - Value) and S_c, S_f, and $S_g = \frac{d_m}{2}$

$\left[\text{Var}(x)\right]^{1/2} = S_x = \left[W_c^2 S_c^2 + W_f^2 S_f^2 + W_g^2 S_g^2\right]^{1/2}$ and $W_c = 0.16$, $W_f = 0.34$, $W_g = 0.50$

$$\text{Var}(d_a) = d_a^2 \left[\frac{\text{Var}(4000)}{(\text{Value}_{4000})^2} + \frac{\text{Var}(m)}{(\text{Value}_m)^2}\right] \quad \text{when} \quad d_a = \frac{\text{WT. Value}_m}{\text{WT. Value}_{4000}}$$

Table 3.17 CALCULATION OF VARIANCE OF DETERIORATION FACTOR: HC, 1968

Vehicle age	Mileage	Chrysler				Ford				GM			
		Value	Upper	d_m	S_c	Value	Upper	d_m	S_f	Value	Upper	d_m	S_g
0	4,000	255	263	8	4.0	270	279	9	4.5	260	268	8	4.0
4	58,200			14	7.0			13	6.5			12	6.0

Vehicle age	S_x	Var(x)	Weighted value	Deterioration factor, d	Var(d)
0	3.00	9.00	260		
4	3.89	15.1	320	1.23	0.000424

Where: $d_m = (\text{Upper} - \text{Value})$ and S_c, S_f, and $S_g = \frac{d_m}{2}$

$$\left[\text{Var}(x)\right]^{1/2} = S_x = \left[W_c^2 S_c^2 + W_f^2 S_f^2 + W_g^2 S_g^2\right]^{1/2} \quad \text{and } W_c = 0.16,\ W_f = 0.34,\ W_g = 0.50$$

$$\text{Var}(d_a) = d_a^2 \left[\frac{\text{Var}(4000)}{(\text{Value}_{4000})^2} + \frac{\text{Var}(m)}{(\text{Value}_m)^2}\right] \quad \text{when} \quad d_a = \frac{\text{WT. Value}_m}{\text{WT. Value}_{4000}}$$

Table 3.18 CALCULATION OF VARIANCE OF DETERIORATION FACTOR: CO, 1969

Model year - 1969

Pollutant - CO

Vehicle age	Mileage	Chrysler				Ford				GM			
		Value	Upper	d_m	S_c	Value	Upper	d_m	S_f	Value	Upper	d_m	S_g
0	4,000	0.89	0.97	0.08	0.04	0.70	0.74	0.04	0.02	1.15	1.20	0.05	0.025
3	46,800	1.17	1.34	0.17	0.085	1.00	1.10	0.10	0.05	1.57	1.66	0.09	0.045

Vehicle age	S_x	Var(x)	Weighted value	Deterioration factor, d	Var(d)
0	0.016	0.000243	0.90		
3	0.031	0.00098	1.43	1.59	0.00200

Where: d_m = (Upper - Value) and S_c, S_f, and $S_g = \frac{d_m}{2}$

$$\left[\mathrm{Var(x)}\right]^{1/2} = S_x = \left[W_c{}^2 S_c{}^2 + W_f{}^2 S_f{}^2 + W_g{}^2 S_g{}^2\right]^{1/2} \quad \text{and } W_c = 0.16,\ W_f = 0.34,\ W_g = 0.50$$

$$\mathrm{Var}(d_a) = d_a{}^2 \left[\frac{\mathrm{Var(4000)}}{(\mathrm{Value}_{4000})^2} + \frac{\mathrm{Var(m)}}{(\mathrm{Value}_m)^2}\right] \quad \text{when} \quad d_a = \frac{\mathrm{WT.\ Value}_m}{\mathrm{WT.\ Value}_{4000}}$$

Table 3.19 CALCULATION OF VARIANCE OF DETERIORATION FACTOR: CO, 1968

Vehicle age	Mileage	Chrysler				Ford				GM			
		Value	Upper	d_m	S_c	Value	Upper	d_m	S_f	Value	Upper	d_m	S_g
0	4,000	0.99	1.05	0.06	0.03	0.93	0.99	0.06	0.03	1.15	1.20	0.05	0.025
4	58,200			0.10	0.05			0.12	0.06			0.08	0.04

Vehicle age	S_x	Var(x)	Weighted value	Deterioration factor, d	Var(d)
0	0.017	0.000283	1.02		
4	0.030	0.00088	1.50	1.47	0.00147

Where: d_m = (Upper - Value) and S_c, S_f, and $S_g = \frac{d_m}{2}$

$$\left[\mathrm{Var}(x)\right]^{1/2} = S_x = \left[W_c^{\,2} S_c^{\,2} + W_f^{\,2} S_f^{\,2} + W_g^{\,2} S_g^{\,2}\right]^{1/2} \quad \text{and } W_c = 0.16,\ W_f = 0.34,\ W_g = 0.50$$

$$\mathrm{Var}(d_a) = d_a^{\,2} \left[\frac{\mathrm{Var}(4000)}{(\mathrm{Value}_{4000})^2} + \frac{\mathrm{Var}(m)}{(\mathrm{Value}_m)^2}\right] \quad \text{when} \quad d_a = \frac{\mathrm{WT.\ Value}_m}{\mathrm{WT.\ Value}_{4000}}$$

Table 3.20 gives variances of the low-mileage emission rates, $Var(c_i)$ for vehicles of model years 1968 through 1973. Since these emission rates were based upon the relation of low-mileage emissions to standards for 1971 and earlier controlled vehicles, the precisions of rates for the 1972 and 1973 models are assumed to equal the precision of 1971 emission rate. Note that basing 1972 and 1973 emission rates on the relation of 1971 emission rates to standards affects the accuracy of the 1972 and 1973 emission rates but does not affect the precision. The following equation was used for that calculation:

$$\frac{Var\ (c_{1972})}{(c_{1972})^2} = \frac{Var\ (c_{1971})}{(c_{1971})^2}$$

3.3.1.3 Weighted annual travel, M_i - The factors for weighted annual travel, M_i, are given in Table 3.1.2-7 of AP-42. These factors were calculated by the formula $M = \frac{ab}{\Sigma ab}$, where a is the fraction of total vehicle miles nationwide (by vehicle age) and b is the average annual miles driven (also by vehicle age). The precision of M_i depends upon the precision of values for the fraction of vehicles in use and for the average annual miles driven.

Values for the fraction of vehicles in use nationwide are obtained from Automobile Facts and Figures.[19] These numbers are very precise, since they are obtained from tabulation of nationwide registration figures. Calculation of automobile emissions for any jurisdiction within the United States could

Table 3.20 VARIANCE OF EMISSION RATE, 1968-1973

Model year	CO		HC		NO_x	
	c_i[a]	$Var(C_i)$	c_i	$Var(C_i)$	c_i	$Var(C_i)$
1968	46	19.6	4.5	0.401	4.3	0.0445
1969	39	5.48	4.4	0.153	5.5	0.0458
1970	36	7.79	3.6	0.0483	5.1	0.0324
1971	34	6.88	2.9	0.0192	4.8	0.0313
1972[b]	19	2.15	2.7	0.0166	4.8	0.0313
1973[b]	19	2.15	2.7	0.0166	2.3	0.00719

[a] Emission rate

[b] 1972 and 1973 rate based upon relationship of low mileage 1971 emissions to standards for 1971 and earlier vehicles. Therefore precision of 1972 and 1973 emission rates equal precision of 1971 emission rate.

Therefore:

$$\frac{Var(C_{1972})}{(C_{1972})^2} = \frac{Var(C_{1971})}{(C_{1971})^2}$$

incorporate registration data from that jurisdiction in lieu of the nationwide figures to determine the fraction of vehicles in use. The precision of the value for fraction of vehicles in use, whether calculated from nationwide or jurisdictional data, is the same since both are based on registration data. The precision value would be very low, based on the assumption that registration data are very precise. Therefore the precision of the value for fraction of vehicles in use is neglected in calculating the precision of the annual travel value, since the precision of the value for annual miles driven will dominate.

The reference for average annual miles driven is a Nationwide Personal Transportation Study[3] of the Department of Transportation. Data from this study are plotted in Figure 3.2 along with the results of least-squares straight-line fit. The variances of the points on this line can be determined by first calculating the standard error of estimate, Sy.x, where:

$$Sy.x = \left[\frac{1}{N-2}\left(\Sigma Y^2 - a\Sigma Y - b\Sigma XY\right)\right]^{1/2}$$

and

$$b = \frac{N\Sigma XY - \Sigma X\Sigma Y}{N\Sigma X^2 - (\Sigma X)^2}, \quad a = \frac{\Sigma Y}{N} - b\,\frac{\Sigma X}{N}$$

Performing this calculation yields:

$$Sy.x = 1337 \text{ miles/vehicle}$$

The variances of the points on the line are then calculated by the equation:

$$\mathrm{Var}(y) = (Sy.x)^2 \left[\frac{1}{N} + \frac{(X - \bar{X})^2}{(X - \bar{X})^2}\right]$$

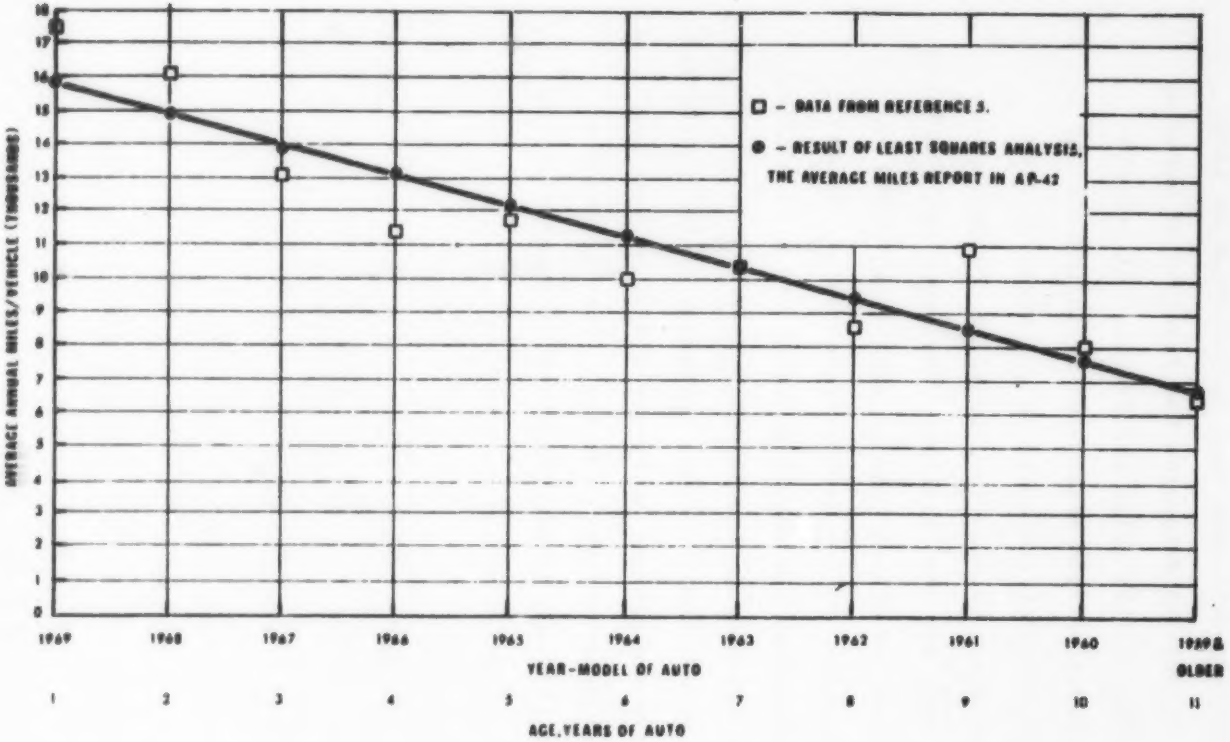

Figure 3.2 Average annual miles driven.

These values, Var(y) are the values for the variance of the annual miles driven (b), or Var(b). Table 3.21 shows the calculation of Var(b).

The variance of the value for weighted annual travel, $\mathrm{Var}(M_i)$ is then calculated:

$$\mathrm{Var}(M_i) = M_i^2 \left[\frac{\mathrm{Var}(a_i b_i)}{(a_i\ b_i)^2} + \frac{\mathrm{Var}\ (\Sigma a_i b_i)}{(\Sigma a_i b_i)^2} \right]$$

Table 3.22 shows the calculation of Var (M_i).

3.3.1.4 Weighted speed adjustment factor, s_i - The equation for the speed adjustment factor (from AP-42) is:

$$s_i = \sum_{j=1}^{n} f_j v_j$$

where: s_i = The weighted speed adjustment factor for the i^{th} model year

f_j = The fraction of total annual vehicle miles traveled at speed (j)

v_j = The vehicular average speed correction factor for average speed (j)

In this project, however, the emission factors in the NEDS computer are segregated by road type (indicated by average speed driven on the roads). Therefore in calculation for purposes of this report, f_i equals 1, thus s_i equals v_j. The average speed correction factor, V, is given in Figure 3.1.1-1 of AP-42. The reference for CO and HC correction factors is McMichael and Rose,[34] who present log graphs of CO and HC emissions versus average route speed, indicating a range of ± 2 units of the standard error of estimate.

To calculate the precision of any point on the graph, the standard error of the estimated value, $S\hat{y}$, is needed:

Table 3.21 VARIANCE OF ANNUAL MILES DRIVEN

x	$(x-\bar{x})^2$	$\frac{(x-\bar{x})^2}{\Sigma(x-\bar{x})^2}$	$\frac{1}{n} + \frac{(x-\bar{x})^2}{\Sigma(x-\bar{x})^2}$	Var(y) y =1000 miles	y = miles
0	36	0.3273	0.4182	0.748	748,000
1	25	0.2273	0.3182	0.568	568,000
2	16	0.1454	0.2363	0.422	422,000
3	9	0.0818	0.1727	0.308	308,000
4	4	0.0364	0.1273	0.241	241,000
5	1	0.0091	0.1000	0.179	179,000
6	0	0	0.0909	0.162	162,000
7	1	0.0091	0.1000	0.179	179,000
8	4	0.0364	0.1273	0.241	241,000
9	9	0.0818	0.1727	0.308	308,000
10	16	0.1454	0.2363	0.422	422,000
11	25	0.2273	0.3182	0.568	568,000
12	36	0.3273	0.4182	0.748	748,000
13	49	0.4454	0.5363	0.959	959,000

$\Sigma(x-\bar{x})^2 = 110$

$n = 11$

$$\text{Var}(y) = Sy.x^2 \left[\frac{1}{n} + \frac{(x-\bar{x})^2}{\Sigma(x-\bar{x})^2}\right]$$

$Sy.x = 1.337$

$Sy.x^2 = 1.788$

Table 3.22 VARIANCE OF WEIGHTED ANNUAL TRAVEL, $Var(m_1)$

Age	Fract. in use (a)	Ave. travel (b)	Var(b)	a x b	Var(ab)	$(a \times b)^2$	m	$\frac{Var(ab)}{(ab)^2}$	$\frac{Var\Sigma(ab)}{[\Sigma(ab)]^2}$	$Var(m) = m^2$	$\left[\frac{Var(ab)}{(ab)^2} + \frac{Var\Sigma(ab)}{[\Sigma(ab)]^2}\right]$
0	0.000	15,900	748,000	0	0	0	0.000	0	0.00021	0	
1	0.078	15,900	568,000	1240	3455	1,537,600	0.107	0.00224	0.00021	0.0000281	
2	0.116	15,000	422,000	1740	5678	3,027,600	0.151	0.00188	0.00021	0.0000477	
3	0.110	14,000	308,000	1540	3727	2,371,600	0.133	0.00157	0.00021	0.0000315	
4	0.098	13,100	241,000	1284	2315	1,648,656	0.111	0.00140	0.00021	0.0000198	
5	0.106	12,200	179,000	1293	2011	1,671,849	0.112	0.00120	0.00021	0.0000177	
6	0.106	11,300	162,000	1198	1821	1,435,204	0.104	0.00127	0.00021	0.0000160	
7	0.088	10,300	179,000	906	1385	820,836	0.078	0.00169	0.00021	0.0000116	
8	0.078	9,400	241,000	733	1465	537,289	0.063	0.00273	0.00021	0.0000117	
9	0.063	8,500	308,000	536	1225	287,296	0.046	0.00426	0.00021	0.0000095	
10	0.041	7,600	422,000	312	711	97,344	0.027	0.00730	0.00021	0.0000055	
11	0.035	6,700	568,000	235	699	55,225	0.020	0.01266	0.00021	0.0000051	
12	0.021	6,700	748,000	141	331	19,881	0.012	0.01665	0.00021	0.0000024	
≥13	0.060	6,700	959,000	402	3452	161,604	0.036	0.02136	0.00021	0.0000280	
			TOTALS:	11560	28275	13,671,984					

$$Var(ab) = (ab)^2 \; \frac{Var(b)}{b^2}$$

$$Var(\Sigma ab) = \Sigma Var(ab)$$

$$\frac{Var\Sigma(ab)}{[\Sigma(ab)]^2} = \frac{28275}{(11560)^2} = 0.00021$$

$$Var(m) = m^2 \left[\frac{Var(ab)}{(ab)^2} + \frac{Var\Sigma(ab)}{[\Sigma(ab)]^2}\right] \quad \text{where } m = \frac{ab}{\Sigma ab}$$

$$S\hat{y} = Sy.x\left[\frac{1}{N} \quad \frac{(X_o-\bar{X})^2}{\Sigma(X - \bar{X})^2}\right]$$

but $(X_o-\bar{X})^2$ and $\Sigma(X-\bar{X})^2$ cannot be determined without the original data. For the purpose of this study, it is assumed that:

$$\frac{(X_o-\bar{X})^2}{\Sigma(X-\bar{X})^2} << \frac{1}{N}$$

hence the term $\frac{(X_o-\bar{X})^2}{\Sigma(X-\bar{X})^2}$ is dropped from the equation, which is simplified:

$$S\hat{y} = \frac{Sy.x}{\sqrt{N}}$$

The standard error of estimate (Sy.x) is read from the graph in Reference 34. It is one-half the range shown of plus two units of the standard error of estimate. The graphs used for the correction factors are based on combined data from Cincinnati and Los Angeles.

From the calculations of $S\hat{y}$, the precision of any point on the curve is calculated by the formula:

$$P = \frac{\text{antilog}\left[\log \hat{y} - S\hat{y}\right] - \hat{y}}{\hat{y}} \quad .$$

where $\hat{y}$ is the estimated value. The precision value is the same for all points along the curve; results of the precision calculations are given below.

Pollutant	Precision of any point on the curve
CO	0.0474
HC	0.0280

The speed correction factors are calculated by dividing the emission rates at 15, 30, 45, and 60 miles per hour by the emission rate at 19.6 miles per hour. The variance of the speed correction factor, $\mathrm{Var}(V_x)$, is calculated

$$\mathrm{Var}(V_x) = V_x^2\left[(P_{19.5})^2 + (P_x)^2\right]$$

Where $V_x = \dfrac{\mathrm{Emissions}_{x\text{-mph}}}{\mathrm{Emissions}_{19.5\ \mathrm{mph}}}$

and $P_{19.5} = P_x$ = precision of any point on the graph. Table 3.23 shows the precisions of HC and CO speed correction factors.

Reference 32 is cited for the NO_x speed correction curve. Since this reference does not indicate how the NO_x speed correction curve was developed from the data, we were unable to calculate the precision of the NO_x speed correction factors. We therefore estimate that the precision of the NO_x speed correction factors would be equal to the average precision of the HC and CO speed correction factors.

Pollutant	Precision	$\frac{\mathrm{Var}(S_i)}{(S_i)^2}$
HC	0.0396	0.00157
CO	0.0670	0.00449
Ave = NO_x	0.0533	0.00303

3.3.1.5 Total Exhaust Emissions, e_n - The total exhaust emissions, e_n, and their precisions are calculated as follows:

$$e_i = c_i d_i m_i s_i$$

$$e_n = \Sigma e_i$$

Table 3.23 PRECISION OF SPEED CORRECTION CURVES FOR CO AND HC

Speed	CO			HC		
	Speed correction factor, V_j	$\mathrm{Var}(V_j)$	$\frac{\mathrm{Var}(V_j)}{(V_j)^2}$	Speed correction factor, V_j	$\mathrm{Var}(V_j)$	$\frac{\mathrm{Var}(V_j)}{(V_j)^2}$
25	0.81	0.00295	0.00449	0.87	0.00119	0.00157
35	0.60	0.00162	0.000449	0.68	0.000725	0.00157
45	0.50	0.00112	0.000449	0.58	0.000528	0.00157
55	0.44	0.000867	0.000449	0.50	0.000393	0.00157

$$\mathrm{Var}(e_i) = (e_i)^2 \left[\frac{\mathrm{Var}(c_i)}{(c_i)^2} + \frac{\mathrm{Var}(d_i)}{(d_i)^2} + \frac{\mathrm{Var}(m_i)}{(m_i)^2} + \frac{\mathrm{Var}(s_i)}{(s_i)^2} \right]$$

$$\mathrm{Var}(e_i) = \Sigma \mathrm{Var}(e_i)$$

$$\text{Standard Deviation, } S_{e_n} = \left[\mathrm{Var}(e_n) \right]^{1/2}$$

$$\text{Precision} = \frac{S_{e_n}}{e_n}$$

Table 3.24 summarizes the precisions of exhaust emission factors for CO, HC, and NO_x. Tables E-1 through E-4, Tables E-5 through E-8, and Tables E-9 through E-12 of Appendix E show respectively the calculations of these precision values.

It is emphasized that the values given here represent the precision of the emission factors and not their accuracy. Although the large sample size upon which the data were based yields very good statistical precision, the data could be highly inaccurate as a characterization of a given population. The accuracy of the emission factors for any jurisdiction within the United States cannot be estimated from the available data.

3.3.1.6 Combined Evaporative and Crankcase Emission Rate, h_i - The combined evaporative and crankcase emission rates are given in Table 3.1.2-3 of AP-42. The precisions of the evaporative and the crankcase emission rates are therefore calculated separately to determine the precision of the combined emission rate.

The data for evaporative HC emissions from LDG's are from an interim report of General Motors Corporation.[35] Interpolating these data at 9.0 RVP, EPA investigators developed emission

Table 3.24 PRECISION OF LIGHT-DUTY GASOLINE-POWERED VEHICLES

Road type	Precision = $\frac{\sigma e}{e}$		
	CO	Exhaust HC	NO_x
Urban	0.036	0.035	0.028
Suburban	0.036	0.035	0.028
Rural	0.036	0.035	0.028
Limited access	0.036	0.035	0.028

rates of 77.8 grams/(vehicle day) and 36.5 grams/(HEW test).[36,37] The precisions of these interpolated values are determined by calculating the standard error of the estimated value, Sy:

$$Sy = Sy \cdot x \left[\frac{1}{N} + \frac{(x_o - \bar{x})^2}{\Sigma (x - \bar{x})^2} \right]^{1/2}$$

In this equation, Sy·x is the standard error of estimate, calculated as follows:

$$Sy \cdot x = \frac{1}{N-2} \left[\Sigma Y^2 - a\Sigma Y - b\Sigma\ XY \right]^{1/2}$$

where:

$$b = \frac{N\Sigma XY - \Sigma X \Sigma Y}{N\ X^2 - (\ X)^2}$$

$$a = \frac{\Sigma Y}{N} - b \frac{\Sigma X}{N}$$

Performing the above calculations gives:

for $y = 77.8 \frac{\text{grams}}{\text{vehicle day}}$, $Sy = 3.27 \frac{\text{grams}}{\text{vehicle day}}$

for $y = 36.5 \frac{\text{grams}}{\text{HEW test}}$, $Sy = 1.22 \frac{\text{grams}}{\text{HEW test}}$

Calculation of LDG evaporative emissions also entails use of the figure of 26 miles driven per day, a value that approximates the nationwide average according to data of the Department of Transportation (Reference 19, page 57). Our earlier analysis of the precision of values for measured vehicle miles on the NEDS area source form (Section 3.2.2.9) indicated that values for the total annual miles driven by all passenger cars are precise within 3.2 percent. Therefore, since the number of vehicles registered is considered precise, the values for average annual miles traveled per vehicle and for average miles driven per day per vehicle are assigned a precision of 3.2 percent.

Evaporative emission rates for pre-1971 (uncontrolled) LDG's are calculated by dividing 77.8 grams/(vehicle day) by 26 miles/day, yielding emissions of 2.99 grams/mile. The nationwide limit on evaporative emissions from 1971 model LDG's was 6 grams/(HEW test).[36,37] The evaporative emission rate for that model year is calculated by dividing 77.8 grams/(vehicle day) by 36.5 grams/(HEW test), multiplying by 6 grams/(HEW test), and dividing by 26 miles/day. This procedure gives an emission rate of 0.49 gram/mile. Regulations for 1972 and newer LDG's limit evaporative emissions to 2 grams/(HEW test).[36] The emission rate for these vehicles is calculated as outlined above, using 2 grams/(HEW test) instead of 6 grams/(HEW test). The resulting emission rate is 0.16 gram/mile. Calculations of the variance of the evaporative emission rates are given in Table 3.25. The results of these calculations are summarized as follows:

Model Year	Evap. (gm/mile)	Var (evap.)
Pre-1971	2.99	0.0249
1971	0.49	0.000938
Post-1971	0.16	0.000100

Uncontrolled crankcase emissions of HC from pre-1963 model-year automobiles are calculated by the following equation:[37]

$$1.1\ \frac{\text{cu ft}}{\text{min}} \times 60\ \frac{\text{min}}{} \times 86\ \frac{\text{lb}}{\text{mole hex}} \times \frac{1\ \text{mole air}}{379\ \text{cu ft}} \times \frac{15000\ \text{mole hex}}{10^6\ \text{mole air}}$$

$$\times\ \frac{1\ \text{hr}}{25\ \text{mi}} \times 454\ \frac{\text{gm}}{\text{lb}} = 4.08\ \frac{\text{gm}}{\text{vehicle mile}}$$

Table 3.25 EVAPORATIVE EMISSIONS FROM LDG

77.8 gm/mile	$S\hat{y} = 3.27$
36.5 gm/ HEW test	$Sy = 1.22$
26 miles/day	Precision = 3.2%

Pre-1971

$$\text{evap} = 77.8\ \frac{\text{gm}}{\text{day}} \div 26\ \frac{\text{mi}}{\text{day}} = 2.99\ \frac{\text{gm}}{\text{mile}}$$

$$\text{Var(evap)} = h^2\left[\left(\frac{S\hat{y}_{day}}{y_{day}}\right)^2 + \left(\frac{P_{\frac{mi}{day}}}{}\right)^2\right] = (2.99)^2\left[\left(\frac{3.27}{77.8}\right)^2 + (0.032)^2\right]$$

$$\text{Var(evap)} = 0.0249$$

1971

$$\text{evap} = \frac{77.8\ \text{gm/day}}{36.5\ \text{gm/HEW test}} \times 6\ \frac{\text{gm}}{\text{test}} \div 26\ \frac{\text{mi}}{\text{day}} = 0.49\ \frac{\text{gm}}{\text{mile}}$$

$$\text{Var(evap)} = h^2\left[\left(\frac{S\hat{y}_{day}}{y_{day}}\right)^2 + \left(\frac{S\hat{y}_{test}}{y_{test}}\right)^2 + \left(P_{\frac{mi}{day}}\right)^2\right] = (0.49)^2\left[\left(\frac{3.27}{77.8}\right)^2 + \left(\frac{1.22}{36.5}\right)^2 + (0.032)^2\right]$$

$$\text{Var(evap)} = 0.000938$$

Post-1971

$$\text{evap} = \frac{77.8\ \text{gm/day}}{36.5\ \text{gm/HEW test}} \times 2\ \frac{\text{gm}}{\text{test}} \div 26\ \frac{\text{mi}}{\text{day}} = 0.16\ \frac{\text{gm}}{\text{mile}}$$

$$\text{Var(evap)} = h^2\left[\left(\frac{S\hat{y}_{day}}{y_{day}}\right)^2 + \left(\frac{S\hat{y}_{test}}{y_{test}}\right)^2 + \left(P_{\frac{mi}{day}}\right)^2\right] = (0.16)^2\left[\left(\frac{3.27}{77.8}\right)^2 + \left(\frac{1.22}{36.5}\right)^2 + (0.032)^2\right]$$

$$\text{Var(evap)} = 0.000100$$

The factors in this equation that affect precision are the average blowby of 1.1 cfm and the average HC concentraton of 15,000 ppm. The other factors in the equation do not affect precision.

The average blowby flow rate and its standard deviation are reported by EPA in Reference 37. Upon examining the data in the reference, we interpret the reported standard deviation to be the standard deviation of the mean, $S_{\bar{x}}$. The reported value of $S_{\bar{x}}$ is 0.113 cfm. Precision of the blowby flow rate is therefore:

$$\text{Precision}_{\text{blowby flow rate}} = \frac{S_{\bar{x}}}{\bar{x}} = \frac{0.113\ \text{cfm}}{1.1\ \text{cfm}} = 0.103$$

The average HC concentration in blowby gases is given in a report of Scott Research Laboratories.[38] By use of data in this reference and the equations:

$$S_x = \frac{\text{Max - Min}}{d_2} \quad \text{and } S_{\bar{x}} = \frac{S_{\bar{x}}}{n}$$

the standard deviation of the mean, $S_{\bar{x}}$ is calculated to be 746 ppm. These calculations are shown in Table 3.26. Precision is then calculated as:

$$\text{Precision}_{\text{HC concentration}} = \frac{S_{\bar{x}}}{\bar{x}} = \frac{746}{15000} = 0.0497$$

The variance of the uncontrolled crankcase emission rate is then calculated by the equation:

$$\text{Var}(y) = y^2 \left[(\text{Precision}_{\text{blowby}})^2 + (\text{Precision}_{\text{HC concentration}})^2\right]$$

$$= (4.08)^2 \left[(0.103)^2 + (0.0497)^2\right] = 0.218$$

Table 3.26 CONCENTRATION OF HC IN AUTOMOTIVE BLOWBY GASES

Total HC by FI, ppm (as Hexane)[a]	
15,000	$S_x = \frac{\text{Max} - \text{Min}}{d_2}$
16,900	
16,200	$S_x = 1670$
13,000	$S_{\bar{x}} = \frac{S_x}{n}$
16,000	
	$S_{\bar{x}} = 746$

[a] Data from Reference 38, page 11.

Crankcase emissions from vehicles of the 1963 through 1967 model years were controlled by devices considered to be 80 percent effective.[37] The emission rates for those models are calculated by reducing the uncontrolled rate by 80 percent; the controlled emission rate therefore is 0.816 gm/mile. We estimate that the precision of the controlled emission rate equals the precision of the uncontrolled emission rate. Thus:

$$\frac{\text{Var}(y_1)}{(y_1)^2} = \frac{\text{Var}(y_2)}{(y_2)^2}$$

and the variance of the controlled rate is:

$$\text{Var (controlled)} = (0.0131)(0.816)^2 = 0.00872$$

The crankcase emission controls for post-1967 model year automobiles are considered 100 percent effective, and emissions are therefore zero. Precision and variance are also considered to be zero for the post-1967 model vehicles.

Calculations for variance of the crankcase emission rates are summarized as follows:

Model year	Crankcase emissions gm/mile	Variance of crankcase emissions
Pre-1963	4.08	0.218
1963 thru 1967	0.816	0.00872
Post-1967	0	0

The individual emission rates for evaporative and crankcase emissions are added to give the combined emission rate, h. The variance of the combined rate is the sum of the variances of the components, as shown below:

Model year	Evaporative emission rate	Var(evap)	Crankcase emission rate	Var (crank)	Combined crankcase and evaporative emission rate, h	Var(h)
Pre-1963	3.0	0.0249	4.1	0.218	7.1	0.243
1963 thru 1967	3.0	0.0249	0.8	0.0087	3.8	0.0336
1968 thru 1970	3.0	0.0249	0	0	3.0	0.0249
1971	0.5	0.00094	0	0	0.5	0.00094
Post-1971	0.2	0.00010	0	0	0.2	0.00010

3.3.1.7 Combined Evaporative and Crankcase Emission Factor, f_n - The factor for combined evaporative and crankcase emissions is calculated by the equation presented earlier:

$$F_n = \Sigma h_i m_i$$

The variance of this emission factor is calculated by the following equations:

$$\mathrm{Var}(f_i) = f_i^2 \left[\frac{\mathrm{Var}(h_i)}{(h_i)^2} + \frac{\mathrm{Var}(m_i)}{(m_i)^2} \right]$$

$$\text{and } \mathrm{Var}(f_n) = \quad \mathrm{Var}(f_i)$$

Calculation of the variance of the combined evaporative and crankcase emission factor is shown in Table 3.27.

3.3.1.8 Total HC Emission Factor Exhaust and Combined Evaporative and Crankcase Emissions - The HC emission factors used in computer calculations are the sum of the exhaust emission factors (e_{HC}) and the combined evaporative and crankcase emission factors (f). The variance of the total HC emission factors therefore is the sum of variances of the exhaust factor and the combined evaporative and crankcase emission factors,

Table 3.27 LIGHT-DUTY GASOLINE-POWERED VEHICLES EVAPORATIVE AND CRANKCASE HYDROCARBON EMISSIONS; ALL ROAD TYPES

Age	Model year	Evap. & crankcase emission rate, h_i			Weighted annual travel, m_i			Evap. & crankcase emission factor, f_i		
		h_i	$Var(h_i)$	$\frac{Var(h_i)}{(h_i)^2}$	m_i	$Var(m_i)$	$\frac{Var(m_i)}{(m_i)^2}$	f_i	$Var(f_n)$	$\Sigma \frac{Var(x)}{x^2}$
1	1973	0.2	0.00010	0.00250	0.107	0.0000281	0.00245	0.0214	0.000002	0.00495
2	1972	0.2	0.00010	0.00250	0.151	0.0000477	0.00209	0.0302	0.000004	0.00459
3	1971	0.5	0.00094	0.00376	0.133	0.0000315	0.00178	0.0665	0.000024	0.00554
4	1970	3.0	0.0249	0.00277	0.111	0.0000198	0.00161	0.333	0.000486	0.00438
5	1969	3.0	0.0249	0.00277	0.112	0.0000177	0.00141	0.336	0.000472	0.00418
6	1968	3.0	0.0249	0.00277	0.104	0.0000160	0.00148	0.312	0.000414	0.00425
7	1967	3.8	0.0336	0.00233	0.078	0.0000116	0.00191	0.296	0.000371	0.00424
8	1966	3.8	0.0336	0.00233	0.063	0.0000117	0.00295	0.239	0.000302	0.00528
9	1965	3.8	0.0336	0.00233	0.046	0.0000095	0.00449	0.175	0.000209	0.00682
10	1964	3.8	0.0336	0.00233	0.027	0.0000055	0.00754	0.103	0.000105	0.00987
11	1963	3.8	0.0336	0.00233	0.020	0.0000051	0.01275	0.0760	0.000087	0.01508
12	1962	7.1	0.243	0.00482	0.012	0.0000024	0.01667	0.0852	0.000156	0.02149
≥13	1961 & older	7.1	0.243	0.00482	0.036	0.0000280	0.02160	0.256	0.001731	0.02642
								Σ= 2.33	Σ=0.00436	

$f_i = h_i m_i$

$f_n = \Sigma f_i$

$Var(f_i) = f_i^2 \left[\frac{Var(h_i)}{(h_i)^2} + \frac{Var(m_i)}{(m_i)^2}\right]$

$Var(f_n) = \Sigma Var(f_i)$

$\sigma f_n = [Var(f_n)]^{1/2}$

$Var(f_n) = 0.00436$

$f_n = 2.33$

$$\text{Var(total HC emission factor)} = \text{Var}(e_{HC}) + \text{Var}(f)$$

The precision of the total HC factor is then:

$$\text{Precision} = \frac{\text{Var(total HC emission factor)}}{(e_{HC} + f)^2}^{1/2}$$

Table 3.28 shows the precision of the total HC emission factors.

3.3.2 Heavy-Duty, Gasoline-Powered Highway Vehicles

The procedures for calculating emission factors for heavy-duty gasoline-powered highway vehicles (HDG) are presented in Section 3.1.4 of AP-42. The HDG exhaust emission factors for CO, HC, and NO_x are calculated using the expression:

$$e_{np} = \sum_{i=n-12}^{n+1} c_i d_i m_i s_i$$

where e_{np} = Emission factor in grams per vehicle mile (g/km) for calendar year (n) and pollutant (p)

c_i = The test procedure emission rate (Table 3.1.4-1) for pollutant (p) in g/mi for the i^{th} model year, at low mileage

d_i = The controlled vehicle pollutant (p) emission deterioration factor for the i^{th} model year at calendar year (n)

m_i = The weighted annual travel of the i^{th} model year vehicles during calendar year (n). The determination of this variable involves the use of the vehicle year distribution

s_i = The weighted speed adjustment factors for the i^{th} model year vehicles

Also, a combined evaporative and crankcase HC emission factor is calculated and added to the exhaust HC emission factor to give total HC emissions from HDG's. The following expression for calculating evaporative and crankcase HC emissions is presented in Section 3.1.4 of AP-42:

Table 3.28 PRECISION OF TOTAL HC EMISSION FACTORS FOR LDG

Road type	Ave. speed, mph	Exhaust HC emission factor, e	Var(e)	Combined evap. and crankcase emission factor, f	Var(f)	Total HC emission factor e+f	Var(total)	Precision, p
Urban	25	4.64	0.0271	2.33	0.0044	6.97	0.0315	0.025
Suburban	35	3.63	0.0165	2.33	0.0044	5.96	0.0209	0.024
Rural	45	3.09	0.0120	2.33	0.0044	5.42	0.0164	0.024
Limited access	55	2.67	0.0089	2.33	0.0044	5.00	0.0133	0.023

where:

$$p = \left[\frac{\text{Var(total)}}{(e + f)^2}\right]^{1/2}$$

$$f_n = \sum_{i=n-12}^{n+1} h_i m_i$$

where: f_n = The combined evaporative and crankcase hydrocarbon emission factor for calendar year (n)

h_i = The combined evaporative and crankcase hydrocarbon emission rate for the ith model year. Emission factors for this source are: pre 1968, 8.2 g/mi (5.1 g/km); and 1968 and later vehicles, 3.0 g/mi (1.9 g/km). In California: 1964-1972, 3.0 g/mi (1.9 g/km); post-1972, 0.2 g/mi (0.1 g/km).

m_i = The weighted annual travel of the ith model year vehicle during calendar year (n)

To calculate the precision of the total HC emission factor, we first determine the precisions of c_i, d_i, m_i, s_i, and h_i.

3.3.2.1 Test Procedure Emission Rate, c_i - Exhaust emission factors for all areas except those of high altitudes and California are given in Table 3.1.4-1 of AP-42. These factors were calculated from data in References 39 through 44 of this report.

The pre-1970 emission rates are calculated from dynamometer test data that simulated on-the-road conditions.[39-41] The precision of these data therefore is the precision of pre-1970 emission rates. Data from References 39 and 40 are used in the precision calculations but not the data from Reference 41 which are not in usable form.

The means and standard deviations by vehicle class are calculated separately for the two data sources and then combined. The mean and standard deviation of the combined data are calculated according to these formulas:

$$\bar{x} = \frac{n_1\bar{x}_1 + n_2\bar{x}_2}{n_1 + n_2}$$

$$s_p = \left[\frac{1}{n_1 + n_2 - 2}\left[(n_1 - 1)s_1^2 + (n_2 - 1)s_2^2\right]\right]^{1/2}$$

$$s_{\bar{x}} = \frac{s_p}{\sqrt{n_1 + n_2}}$$

Emissions of the three vehicle classes (combined data) are averaged into one emission rate for all trucks. Because a straight average would not realistically reflect the national truck population, the following weighting factors are used to combine the three vehicle classes. These data are from the 1967 Census of Transportation (Reference 45):

Vehicle class (Gross vehicle weight)	Number of trucks	Percent of total
II (6,001 to 10,000 lb)	11,318,000	73.7
III (10,001 to 19,500 lb)	2,098,000	13.7
IV (19,501 lb)	1,944,000	12.6

The weighted average and weighted standard deviation are calculated from the following equations:

$$\text{Weighted average} = 0.737\ \bar{X}_{II} + 0.137\ \bar{X}_{III} + 0.126\ \bar{X}_{IV}$$

$$S_{\bar{X}_{AVE}} = [(0.737)^2(S_{\bar{X}_{II}})^2 + (0.137)^2(S_{\bar{X}_{III}})^2 + (0.126)^2 (S_{\bar{X}_{IV}})^2]^{1/2}$$

These calculations and calculations of variance are given in Tables 3.29, 3.30, and 3.31 for pre-1970 emission rates of CO, HC, and NO_x, respectively.

Emission factors for 1970 through 1973 trucks were compiled from References 39 through 44 of this report. The emission rates are based on both dynamometer and on-the-road testing. References 42 and 43 are the sources for calculation of emission rates.

The dynamometer emission test data are given in Reference

Table 3.29 VARIANCE OF CO EMISSION RATES: PRE-1970 GASOLINE TRUCKS

Vehicle class	Ethyl Corp. (3.1.4-6, Ref.1)			SWRI (3.1.4-6, Ref. 2)			Average			
	n_1	Chassis dyndata CO/CO_2 scale (gm/mi) ($\bar{x}_i$)	S_1	n_2	Emissions $\bar{x}_2$ (gm/mi)	S_2	n_1+n_2	$\bar{x}$	S_p	$\sigma_{\bar{x}}$
II	20	104	28.6	30	154	41.9	50	134	37.2	5.26
III	20	144	43.2	47	183	47.7	67	171	46.4	5.67
IV	20	138	54.6	57	162	63.1	77	156	61.1	6.96

Where $\bar{x} = \dfrac{n_1\bar{x}_1 + n_2\bar{x}_2}{n_1 + n_2}$

$$S_p = \left\{\frac{1}{n_1+n_2-2} \left[(n_1 - 1)S_1^2 + (n_2 - 1)S_2^2\right]\right\}$$

$$\sigma_{\bar{x}} = \frac{S_p}{\sqrt{n_1+n_2}}$$

Weighted Average

	Emissions (gm/mi)	STD. deviation	Var(C)	$\frac{Var(C)}{C^2}$
Calculated	142	4.05	16.4	.00081
AP-42	140		15.9[a]	.00081

$$\text{WT. Average} = .737\bar{x}_{II} + .137\bar{x}_{III} + .126\bar{x}_{IV}$$

$$\text{ave} = \left[(.737)^2(\sigma_{\bar{x}_{II}})^2 + (.137)^2(\sigma_{\bar{x}_{III}})^2 + (.126)^2(\sigma_{\bar{x}_{IV}})^2\right]^{1/2}$$

[a] where $\dfrac{Var(C_1)}{(C_1)^2} = \dfrac{Var(C_2)}{(C_2)^2}$

Table 3.30 VARIANCE OF EXHAUST HC EMISSION RATES: PRE-1970 GASOLINE TRUCKS

Vehicle class	Ethyl Corp. (3.1.4-6, Ref.1)			SWRI (3.1.4-6, Ref. 2)			Average			
		Chassis dyndata CO/CO_2 scale			Emissions					
	n_1	(gm/mi) ($\bar{x}_i$)	S_1	n_2	$\bar{x}_2$ (gm/mi)	S_2	n_1+n_2	$\bar{x}$	S_p	$\sigma_{\bar{x}}$
II	20	19.8	3.63	30	34.4	7.63	50	22.6	6.36	0.899
III	20	25.7	12.2	47	21.3	7.04	67	22.6	8.86	1.06
IV	20	24.6	9.03	57	21.8	9.85	77	22.5	7.65	1.10

Where $\bar{x} = \frac{n_1\bar{x}_1 + n_2\bar{x}_2}{n_1 + n_2}$

$$S_p = \left\{ \frac{1}{n_1+n_2-2} \left[(n_1 - 1)S_1^2 + (n_2 - 1)S_2^2 \right] \right\}$$

$$\sigma_{\bar{x}} = \frac{S_p}{\sqrt{n_1+n_2}}$$

Weighted Average

	Emissions (gm/mi)	STD. deviation	Var(C)	$\frac{\text{Var(C)}}{C^2}$
Calculated	22.6	0.692	0.479	.00094
AP-42	17		0.272[a]	.00094

WT. Average $= .737\bar{x}_{II} + .137\bar{x}_{III} + .126\bar{x}_{IV}$

ave $= \left[(.737)^2(\sigma_{\bar{x}_{II}})^2 + (.137)^2(\sigma_{\bar{x}_{III}})^2 + (.126)^2(\sigma_{\bar{x}_{IV}})^2 \right]^{1/2}$

[a] where $\frac{\text{Var}(C_1)}{(C_1)^2} = \frac{\text{Var}(C_2)}{(C_2)^2}$

Table 3.31 VARIANCE OF NO_x EMISSION RATES: PRE-1970 GASOLINE TRUCKS

Vehicle class	Ethyl Corp. (3.1.4-6, Ref.1)			SWRI (3.1.4-6, Ref. 2)			Average			
	n_1	Chassis dyndata CO/CO_2 scale (gm/mi) ($\bar{x}_i$)	S_1	n_2	Emissions $\bar{x}_2$ (gm/mi)	S_2	n_1+n_2	$\bar{x}$	S_p	$\sigma_{\bar{x}}$
II	20	6.36	2.54	30	6.31	2.19	50	6.33	2.33	0.330
III	20	15.5	6.63	47	7.40	3.04	67	9.82	4.40	0.538
IV	20	21.0	6.58	57	7.72	3.30	77	11.2	4.37	0.498

Where $\bar{x} = \frac{n_1\bar{x}_1 + n_2\bar{x}_2}{n_1 + n_2}$

$$S_p = \left\{\frac{1}{n_1+n_2-2}\left[(n_1 - 1)S_1{}^2 + (n_2 - 1)S_2{}^2\right]\right\}$$

$$\sigma_{\bar{x}} = \frac{S_p}{\sqrt{n_1+n_2}}$$

Weighted Average

	Emissions (gm/mi)	STD. deviation	Var(C)	$\frac{Var(C)}{C^2}$
Calculated	7.42	0.262	.0686	.00125
AP-42	9.4		0.110[a]	.00125

$$\text{WT. Average} = .737\bar{x}_{II} + .137\bar{x}_{III} + .126\bar{x}_{IV}$$

$$\text{ave} = \left[(.737)^2(\sigma_{\bar{x}_{II}})^2 + (.137)^2(\sigma_{\bar{x}_{III}})^2 + (.126)^2(\sigma_{\bar{x}_{IV}})^2\right]^{1/2}$$

[a] where $\frac{Var(C_1)}{(C_1)^2} = \frac{Var(C_2)}{(C_2)^2}$

43 in terms of grams of pollutant per pound of fuel. To convert to road emissions in units of grams of pollutants per mile traveled, the rate for gm/lb of fuel is divided by a dynamometer-to-road emission correction factor, multiplied by a fuel density factor, and divided by an average mile per gallon factor. The precision of the value for road emissions in grams per mile is determined by the precision of the factors with which the value is calculated. Standard deviations of the emission test data in grams per pound of fuel are presented in Tables 3.32, 3.33, and 3.34 for CO, HC, and NO_x respectively. The miles per gallon figure and dynamometer-to-road correction factors for HC, CO, and NO_x are based on test data in Reference 42. Standard deviations of these data are given in Table 3.35.

The emission rate is then calculated using the following equation:

$$\text{Emissions, } C = \frac{\text{lb}}{\text{lb of fuel}} \times \frac{1}{\text{Dyn/Road Correction}} \times \frac{\text{lb fuel}}{\text{gal}} \times \frac{1}{\text{mpg}}$$

In this equation, the lb fuel/gallon factor is considered precise and therefore is not used in calculation of precision of the emission rate. The variance of the AP-42 emission rates for 1970-1973 models is then calculated using the calculated variance and the relationship:

$$\frac{\text{Var } (C_1)}{(C_1)^2} = \frac{\text{Var } (C_2)}{(C_2)^2}$$

Table 3.32 VARIANCE OF CO EMISSION RATES: 1970-73 GASOLINE TRUCKS

Vehicle class	$\frac{\text{grams}}{\text{lb of fuel}}$	σ	n	$\frac{\sigma}{n} = \sigma_{\bar{x}}$	Percent of total[a]
II	96.7	35.1	58	4.61	73.7
III	63.2	29.5	20	6.60	13.7
IV	107.5	40.5	67	4.95	12.6

Where $\sigma = \left[\frac{n(\Sigma x^2) - (\Sigma x)^2}{n(n-1)}\right]$

Weighted average

96.7 x 0.737 + 63.2 x 0.137 + 108 x 0.126 = 71.3 + 8.7 + 13.6

Wt. Average = 93.6 grams/lb of fuel

$$\sigma_{\bar{x}} \text{ ave} = \left[(0.737)^2(\sigma_{\bar{x}_{II}})^2 + (0.137)^2(\sigma_{\bar{x}_{III}})^2 + (0.126)^2(\sigma_{\bar{x}_{IV}})^2\right]$$

$$\left[(0.737)^2(4.61)^2 + (0.137)^2(6.60)^2 + (0.126)^2(4.95)^2\right]$$

$$= 3.57 \text{ g/mi}$$

[a] Section 3.1.4-6, Reference 44.

Table 3.33 VARIANCE OF EXHAUST HC EMISSION RATES:
1970-73 GASOLINE TRUCKS

Vehicle class	$\frac{\text{grams}}{\text{lb of fuel}}$	σ	n	$\frac{\sigma}{n} = \sigma_{\bar{x}}$	Percent of total
II	9.99	2.41	58	0.316	
III	9.31	1.98	20	0.443	
IV	12.44	8.05	67	0.983	

Where $\sigma = \left[\frac{n(\Sigma x^2) - (\Sigma x)^2}{n(n-1)}\right]$

Weighted average

9.99 x 0.737 + 9.31 x 0.137 + 12.44 x 0.126 = 7.36 + 1.28 + 1.57

Wt. Average = 10.21 grams/lb of fuel

$$\sigma_{\bar{x}}\text{ ave} = \left[(0.737)^2(\sigma_{\bar{x}_{II}})^2 + (0.137)^2(\sigma_{\bar{x}_{III}})^2 + (0.126)^2(\sigma_{\bar{x}_{IV}})^2\right]$$

$$\left[(0.737)^2(0.316)^2 + (0.137)^2(0.443)^2 + (0.126)^2(0.983)^2\right]$$

$$= 0.271 \text{ g/mi}$$

Table 3.34 VARIANCE OF NO_x EMISSION RATES: 1970-73 GASOLINE TRUCKS

Vehicle class	$\frac{\text{grams}}{\text{lb of fuel}}$	σ	n	$\frac{\sigma}{n} = \sigma_{\bar{x}}$	Percent of total
II	14.23	6.63	58	0.871	
III	18.67	5.38	20	1.00	
IV	11.25	5.16	67	0.63	

$$\text{Where } \sigma = \left[\frac{n(\Sigma x^2) - (\Sigma x)^2}{n(n-1)}\right]$$

Weighted average

$$14.23 \times 0.737 + 18.67 \times 0.137 + 11.25 \times 0.126 = 10.49 + 2.56 + 1.42$$

Wt. Average = 14.47 grams/lb of fuel

$$\sigma_{\bar{x}} \text{ ave} = \left[(0.737)^2(\sigma_{\bar{x}_{II}})^2 + (0.137)^2(\sigma_{\bar{x}_{III}})^2 + (0.126)^2(\sigma_{\bar{x}_{IV}})^2\right]$$

$$\left[(0.737)^2(0.871)^2 + (0.137)^2(1.2)^2 + (0.126)^2(0.63)^2\right]$$

$$= 0.667 \text{ g/mi}$$

Table 3.35 STANDARD DEVIATIONS OF DATA IN REFERENCE 41

	Average	$S_{\bar{x}}$
Miles per gallon	5.77	0.228
Dynamometer/road correction factor		
HC	0.85	0.0439
CO	0.68	0.0633
NO_x	1.22	0.0616

Where: $S_{\bar{x}} = \frac{\text{standard deviation}}{\sqrt{n}}$

Calculations of variance of the AP-42 emission rates for 1970-1973 model trucks are shown in Table 3.36.

3.3.2.2 Deterioration Factor, d_i - Deterioration factors for HDG apply only to 1975 and later California vehicles. The deterioration factor for all other HDG is 1. Therefore, the deterioration factor used in this report for HDG calculations is 1. and the precision of this factor is 0.

3.3.2.3 Weighted Annual Travel, m_i - The factors for weighted annual travel, m_i, are given in Table 3.1.4-3 of AP-42. These factors were calculated by the formula $m = \frac{ab}{\Sigma ab}$, where a is the fraction of total vehicles in use nationwide (by vehicle age) and b is the average annual miles driven (also by vehicle age). The precision of m_i, then, depends upon the precision of both the fraction of vehicles in use and the average annual miles driven.

The fraction of vehicles in use nationwide is obtained from 1971 Motor Truck Facts.[46] These numbers are very precise, since they are obtained from nationwide registration figures. Calculations of truck emissions for any jurisdiction within the United States could use registration data from that jurisdiction in lieu of the nationwide figures to determine the fraction of vehicles in use. Precision would be the same, since both calculations are based on registration data. The precision value would be very low, since registration data are very precise. Therefore the precision of the value for fraction of vehicles in use is not used in calculating precision of the annual travel value.

Table 3.36 VARIANCE OF THE EMISSION RATE FROM 1970-1973 MODEL GASOLINE TRUCKS

Pollutant	Emissions, g gm/lb of fuel			Dynamometer correction, γ			Conversion factor, $\frac{\text{lb fuel}}{\text{gal}}$	Miles per gallon			Calculated emission rate		
	$\bar{g}$	$\sigma_{\bar{g}}$	$\frac{Var(g)}{(g)^2}$	$\frac{1}{\bar{\gamma}}$	$\sigma_{\bar{\gamma}}$	$\frac{Var(\gamma)}{(\gamma)^2}$		$\frac{1}{\overline{mpg}}$	$\sigma_{\overline{mpg}}$	$\frac{Var(mpg)}{(mpg)^2}$	C_1	$\Sigma \frac{Var(x)}{x^2}$	$Var(C_1)$
CO	93.6	3.57	0.00145	$\frac{1}{0.68}$	0.0633	0.00867	6.24	$\frac{1}{6.21}$	0.228	0.00135	138	0.01147	218
HC (exhaust)	10.21	0.271	0.00070	$\frac{1}{0.85}$	0.0439	0.00267	6.24	$\frac{1}{6.21}$	0.228	0.00135	12.1	0.00472	0.691
NO_x	14.47	0.667	0.00212	$\frac{1}{1.22}$	0.0616	0.00255	6.24	$\frac{1}{6.21}$	0.228	0.00135	11.9	0.00602	0.852

where:

$$C_1 \left(\frac{gm}{mi}\right) = g \times \frac{1}{\gamma} \times \frac{\text{lb fuel}}{\text{gal}} \times \frac{1}{mpg}$$

$$\frac{Var(x)}{(x)^2} = \left(\frac{\sigma_{\bar{x}}}{\bar{x}}\right)^2$$

$$Var(C_1) = (C_1)^2 \left[\left(\frac{\sigma_{\bar{g}}}{\bar{g}}\right)^2 + \left(\frac{\sigma_{\bar{\gamma}}}{\bar{\gamma}}\right)^2 + \left(\frac{\sigma_{\overline{mpg}}}{\overline{mpg}}\right)^2\right]$$

Pollutant	AP-42 Emission rate, C_2	$Var(C_2)$	$\frac{Var(C_2)}{(C_2)^2}$
CO	130	194	0.01147
HC (exhaust)	16	1.21	0.00472
NO_x	9.2	0.510	0.00602

where:

$$\frac{Var(C_1)}{(C_1)^2} = \frac{Var(C_2)}{(C_2)^2}$$

The 1967 Census of Transportation[45] is the source of data on average miles per truck. The value for average miles per truck is computed by dividing annual truck miles (according to year model) by the corresponding number of trucks. The reference provides data on the sampling variability of the number of trucks, but not for the truck miles or precision of average miles per truck. However, the Census reports that the sampling variability of values for truck-miles is larger than the variability shown for the corresponding estimate of the number of trucks. Since it is not possible to determine the magnitude of the difference in variability, the variability of the truck-miles figure is assumed to be equal to the variability of the number of trucks. Therefore the variance of the annual miles driven is:

$$\text{Var (b)} = b^2 \left[\frac{S_t^2}{t^2} + \frac{S_m^2}{m^2} \right]$$

where $b = \frac{t}{m}$, average annual miles driven

t = number of trucks

m = truck miles

Since the precision of truck-miles is assumed to equal the precision of number of trucks, the equation reduces to:

$$\text{Var (b)} = b^2 \; [2 \text{ X } \frac{S_t^2}{t^2}]$$

The variance and precision of values for average annual miles driven are given in Table 3.37.

The variance of the weighted annual travel, Var (m_i), is then calculated:

Table 3.37 VARIANCE OF AVERAGE ANNUAL MILES

Age	Year model	Percent of total trucks	Sampling variability, %	$\frac{\sigma_{\bar{x}}}{\bar{x}}$	Precision = $\left(\frac{\sigma_{\bar{x}}}{\bar{x}}\right)^2$
1 and 2	1966 & '67	16.5	0.3	0.3/16.5	0.00033
3 and 4	1964 & '65	18.7	0.2	0.2/18.7	0.00011
5 to 8	1960 to'63	23.8	0.2	0.2/23.8	0.00007
9 & older	Pre 1960	41.0	0.2	0.2/41.0	0.00002

Assumed precision of number of trucks and truck miles were equal

Therefore: Var(b) = b^2[2 x (Precision of number of trucks)]

Age	b	Precision of number of trucks	$\frac{\mathrm{Var(b)}}{(\mathrm{b})^2}$	Var(b)
1 and 2	17,200	0.00033	0.00066	195,254
3 and 4	15,800	0.00011	0.00022	54,921
5 and 6	13,000	0.00007	0.00014	23,660
7 and 8	11,000	0.00007	0.00014	16,940
9 and 10	9,000	0.00002	0.00004	3,240
11 & older	5,500	0.00002	0.00004	1,210

$$\mathrm{Var(b)} = b^2 \left[\frac{\sigma_T^2}{T^2} + \frac{\sigma_m^2}{m^2}\right]$$

T = number of trucks
m = truck miles

$$\text{Var}(m_i) = m_i^2 \left[\frac{\text{Var}(a_i b_i)}{(a_i b_i)^2} + \frac{\text{Var}(\Sigma a_i b_i)}{(\Sigma a_i b_i)^2}\right]$$

Table 3.38 shows the calculation of $\text{Var}(m_i)$.

3.3.2.4 Weighted Speed Adjustment Factor, s_i - The speed adjustment factors for LDG are also used for HDG. This affects the accuracy of HDG emission values but the precision of the speed adjustment factors remain the same. The section on LDG speed correction factors gives details of the calculations, which yield the following:

Pollutant	Precision	$\frac{\text{Var}(S_i)}{(S_i)^2}$
HC	0.0396	0.00157
CO	0.0670	0.00449
Ave = NO_x	0.0533	0.00303

3.3.2.5 Total Exhaust Emissions, e_n - The total HDG exhaust emissions, e_n, and their precisions are calculated as follows:

$$e_i = c_i d_i m_i s_i$$

$$e_n = \Sigma e_i$$

$$\text{Var}(e_i) = (e_i)^2 \left[\frac{\text{Var}(C_i)}{(C_i)^2} + \frac{\text{Var}(d_i)}{(d_i)^2} + \frac{\text{Var}(m_i)}{(m_i)^2} + \frac{\text{Var}(s_i)}{(s_i)^2}\right]$$

$$\text{Var}(e_n) = \Sigma\,\text{Var}(e_i)$$

Standard Deviation, $S_{e_n} = [\text{Var}(e_n)]^{1/2}$

$$\text{Precision} = \frac{S_{e_n}}{e_n}$$

Table 3.38 VARIANCE OF WEIGHTED ANNUAL TRAVEL, $Var(m_i)$ FOR GASOLINE TRUCKS

Age	Fract. in use, (a)	Ave. travel, (b)	a x b	$\frac{Var(b)}{(b)^2} = \frac{Var(ab)}{(ab)^2}$	Var(ab)	m	$\frac{Var[\Sigma(ab)]}{[\Sigma(ab)]^2}$	$\frac{Var(m)}{(m)^2}$	Var(m)
0	0.000	17,200	0	0.00066	0	0.000	0	0	0
1	0.071	17,200	1221	0.00066	984	0.107	0.00003	0.00069	78×10^{-7}
2	0.106	17,200	1823	0.00066	2193	0.159	0.00003	0.00025	174×10^{-7}
3	0.087	15,800	1375	0,00022	416	0.120	0.00003	0.00025	36×10^{-7}
4	0.081	15,800	1280	0.00022	360	0.112	0.00003	0.00017	31×10^{-7}
5	0.084	13,000	1090	0.00014	166	0.095	0.00003	0.00017	15×10^{-7}
6	0.076	13,000	988	0.00014	137	0.086	0.00003	0.00017	17×10^{-7}
7	0.065	11,000	715	0.00014	72	0.062	0.00003	0.00017	6×10^{-7}
8	0.055	11,000	605	0.00014	51	0.052	0.00003	0.00017	4×10^{-7}
9	0.047	9,000	423	0.00004	7	0.037	0.00003	0.00007	1×10^{-7}
10	0.035	9,000	315	0.00004	4	0.028	0.00003	0.00007	$.5 \times 10^{-7}$
11	0.037	5,500	204	0.00004	2	0.018	0.00003	0.00007	$.2 \times 10^{-7}$
12	0.033	5,500	182	0.00004	1	0.016	0100003	0.00007	$.2 \times 10^{-7}$
≥ 13	0.223	5,500	1226	0.00004	60	0.108	0.00003	0.00007	8×10^{-7}
		TOTALS:	11447	.00318	4453				

Assumed variance of a is negligible because of the large sample (nationwide figures).

$$Var(ab) = (ab)^2 \left[\frac{Var(b)}{(b)^2}\right] \qquad \frac{Var(ab)}{(ab)^2} = \frac{Var(b)}{(b)^2}$$

$$Var(\Sigma ab) = \Sigma Var(ab)$$

$$\frac{Var(m_i)}{(m_i)^2} = \left[\frac{Var(ab)}{(ab)^2} + \frac{Var(\Sigma ab)}{(\Sigma ab)^2}\right]$$

Table 3.39 summarizes the precisions of the CO, HC, and NO_x exhaust emission factors for HDG's. Tables F-1 through F-4, Tables F-5 through F-8, and Tables F-9 through F-12, Appendix F, show respectively the calculations for precision of CO, HC, and NO_x factors.

It is emphasized again that these calculations show the precision of the emission factors but do not reflect their accuracy.

3.3.2.6 Combined Evaporative and Crankcase Emission Rate, h_i - The combined evaporative and crankcase emission rates for HDG's are presented on page 3.1.4-1 of AP-42. To determine the precision of the combined emission rate, we first calculate separately the precisions of both the evaporative and the crankcase emission rates.

Because no information is available concerning evaporative emissions from HDG vehicles, we assume that the rate is equal to the LDG uncontrolled rate of 2.99 grams/mile.[37] Although this assumption affects the accuracy of the HDG evaporation rate, the precision is the same as that for the uncontrolled LDG rate. The variance of the HDG evaporation rate, therefore, is 0.0249.

The crankcase emission rate for uncontrolled HDG's is calculated by multiplying the uncontrolled LDG emission rate (4.08 gm/mile) by the ratio of exhaust volumes (HDG/LDG).[37] This calculation gives a rate of 5.2 gm/mile.[36] Calculation of the precision of the HDG crankcase emission rate includes not only the precision of the LDG crankcase emission rate, but also the

Table 3.39 PRECISION OF HEAVY-DUTY, GASOLINE-POWERED HIGHWAY VEHICLE EXHAUST EMISSION FACTORS

Road type	Precision = $\frac{\sigma e}{e}$		
	CO	Exhaust HC	NO_x
Urban	0.034	0.023	0.028
Suburban	0.034	0.023	0.028
Rural	0.035	0.023	0.028
Limited access	0.035	0.023	0.028

precisions of the HDG and LDG flow rates. Since the references give no data on determination of LDG and HDG exhaust volumes we estimate that the precision of each of the exhaust volumes equals the precision of the LDG blowby rate, which earlier was calculated as 0.103.

The variance of the HDG crankcase emission rate is calculated by the following equation:

$$\mathrm{Var}(\mathrm{HDG}_{\mathrm{crankcase}}) = (5.2)^2 \left[\frac{\mathrm{Var}(\mathrm{LDG}_{\mathrm{crankcase}})}{(4.08)^2} + 2(\mathrm{Precision}_{\mathrm{LDG\ flow\ rate}})^2\right] = 0.927$$

Starting in 1968, all HDG's were required to have controls that were 100 percent effective in eliminating crankcase emissions. Therefore, the values for crankcase emission rate and variances for 1968 and later HDG's are zero.

The combined crankcase and evaporative emission rates for HDG's, and their variances, are as follows:

Model year	Evaporative emission rate	Var (evap)	Crankcase emission rate	Var (crank)	Combined crankcase and evaporative emission rate, h	Var(h)
Pre-1968	3.0	0.0249	5.2	0.927	8.2	0.952
1968 and later	3.0	0.0249	0	0	3.0	0.0249

3.3.2.7 Combined Evaporative and Crankcase Emission Factor, f_n - The combined evaporative and crankcase emission factor is calculated by the equation presented earlier:

$$f_n = \Sigma h_i m_i$$

The variance of the emission factor is calculated by the following equations:

$$\text{Var}(f_i) = f_i^2 \quad \frac{\text{Var}(h_i)}{(h_i)^2} + \frac{\text{Var}(m_i)}{(m_i)^2}$$

$$\text{and } \text{Var}(f_n) = \text{Var}(f_i.$$

Calculations of the variance of the combined evaporative and crankcase emission factor are shown in Table 3.40.

3.3.2.8 Total Exhaust and Combined Evaporation and Crankcase HC Emission Factors - The HC emission factors used in the computer calculations are the sum of the exhaust emission factors (e_{HC}) and the combined evaporative and crankcase emission factors (f). The variance of the total HC emission factors is therefore the sum of the variances of exhaust and combined evaporative and crankcase emission factors,

$$\text{Var(total HC emission factor)} = \text{Var}(e_{HC}) + \text{Var}(f)$$

The precision of the total HC factor is then:

$$\text{Precision} = \frac{\text{Var(total HC emission factor)}}{(e_{HC} + f)^2}^{1/2}$$

Table 3.41 shows the precision of the total HC emission factor.

3.3.3 Heavy-Duty, Diesel-Powered Highway Vehicles

Emission factors for heavy-duty, diesel-powered highway vehicles (HDD) are given in Section 3.1.5 of AP-42. These emission factors apply to all HDD's regardless of vehicle speeds, geographical location, or vehicle age. The reference cited in AP-42 for calculation of the emission factors is a compilation

Table 3.40 HEAVY-DUTY, GASOLINE-POWERED VEHICLES EVAPORATIVE AND CRANKCASE HYDROCARBON EMISSIONS; ALL ROAD TYPES

Age	Model year	Evap. & crankcase emission rate, h_i			Weighted annual travel, m_i			Evap. & crankcase emission factor, ℓ_i		
		h_i	$Var(h_i)$	$\frac{Var(h_i)}{(h_i)^2}$	m_i	$Var(m_i)$	$\frac{Var(m_i)}{(m_i)^2}$	ℓ_i	$Var(\ell_n)$	$\Sigma \frac{Var(x)}{x^2}$
1	1973	3.0	0.0249	0.00277	0.107	78×10^{-7}	0.00069	0.321	0.00036	0.00346
2	1972	3.0	0.0249	0.00277	0.159	174×10^{-7}	0.00069	0.477	0.00079	0.00346
3	1971	3.0	0.0249	0.00277	0.120	36×10^{-7}	0.00025	0.360	0.00039	0.00302
4	1970	3.0	0.0249	0.00277	0.112	31×10^{-7}	0.00025	0.336	0.00034	0.00302
5	1969	3.0	0.0249	0.00277	0.095	15×10^{-7}	0.00017	0.285	0.00024	0.00294
6	1968	3.0	0.0249	0.01416	0.086	17×10^{-7}	0.00017	0.258	0.00020	0.00294
7	1967	8.2	0.0952	0.01416	0.062	6×10^{-7}	0.00017	0.508	0.00370	0.01433
8	1966	8.2	0.952	0.01416	0.052	4×10^{-7}	0.00017	0.426	0.00260	0.01433
9	1965	8.2	0.952	0.01416	0.037	1×10^{-7}	0.00007	0.303	0.00131	0.01423
10	1964	8.2	0.952	0.01416	0.028	0.5×10^{-7}	0.00007	0.230	0.00075	0.01423
11	1963	8.2	0.952	0.01416	0.018	0.2×10^{-7}	0.00007	0.148	0.00031	0.01423
12	1962	8.2	0.952	0.01416	0.016	0.2×10^{-7}	0.00007	0.131	0.00024	0.01423
≥13	1961 & older	8.2	0.952	0.01416	0.108	8×10^{-7}	0.00007	0.866	0.01117	0.01423
								Σ=4.67	Σ=0.0224	

$\ell_i = h_i m_i$

$\ell_n = \Sigma \ell_i$

$Var(\ell_i) = \ell_i^2 \left[\frac{Var(h_i)}{(h_i)^2} + \frac{Var(m_i)}{(m_i)^2} \right]$

$Var(\ell_n) = \Sigma Var(\ell_i)$

$\sigma \ell_n = [Var(\ell_n)]^{1/2}$

$Var(\ell_n) = 0.0224$

$\ell_n = 4.67$

Table 3.41 PRECISION OF TOTAL HC EMISSION FACTORS FOR HDG

Road type	Ave. speed (mph)	Exhaust HC emission factor, e	Var(e)	Combined evap. and crackcase emission factor, f	Var(f)	Total HC emission factor e+f	Var(total)	Precision, P
Urban	25	14.4	0.105	4.7	0.0224	19.1	0.127	0.019
Suburban	35	11.2	0.0644	4.7	0.0224	15.9	0.0868	0.019
Rural	45	9.6	0.0469	4.7	0.0224	14.3	0.0693	0.018
Limited access	55	8.3	0.0348	4.7	0.0224	13.0	0.0572	0.018

Where:

$$P = \left[\frac{\text{Var(total)}}{(e + f)^2}\right]^{1/2}$$

of data, that gives only derived emission factors.[47] Since the reference does not provide enough data from which to calculate the precision of the emission factors, we assume that the precision of the NO_x emission factor for HDD's is equal to the precision of the emission factor for uncontrolled (pre-1970) HDG's, which was earlier determined as:

$$\text{Precision} = \left[\frac{\text{Var}(C_i)}{(C_i)^2}\right]^{1/2} = 0.00125^{1/2} = 0.035$$

The precision of the NO_x emission factor for HDD's therefore is 0.035.

4.0 COMPUTERIZATION OF QUALITY ANALYSIS

4.1 INTRODUCTION

SIEFA is designed to prepare an inventory of point and area sources of air contaminant emissions for a specified geographical area. The format for the output is shown in Figure 4.1. In addition to showing the total quantity of emissions from selected categories of point and area sources, the output provides an indication of both precision and accuracy of the estimated emissions.

Development of precision values for point and area sources has been described in detail in Sections 2.0 and 3.0; these precision values are given in SIEFA format as standard deviations of the estimated emission values. As discussed earlier, a quantitative evaluation of the accuracy of emission values cannot be performed in the same manner, since no means are available by which to determine the 'true' value of a given emissions figure. We can, however, enhance the accuracy of emissions estimates by approximating emission values in cases where data are not sufficient to yield sound estimates. Thus, rather than compiling an inventory in which some values are simply omitted, we supply an approximate value based on known factors (discussed in

```
 1                                   NEDS Reliability Analysis
 2
 3                                    (Geographical Region)1
 4
 5                                     (Pollutant Name)2
 6
 7                                   Emissions in Tons   Year      Percent    No. of Sources    Est. & Approx.
 8                                         Total        Std. Dev   Std. Dev    Approximated       Emissions
 9
10
11  FUEL COMBUSTION
12  ***************
13       EXTERNAL COMBUSTION
14            RESIDENTIAL FUEL (AREA)
15                 ANTHRACITE COAL
16                 BITUMINOUS COAL
17                 DISTILLATE OIL
18                 RESIDUAL OIL
19                 NATURAL GAS
20                 WOOD
21                 TOTAL (RESIDENTIAL)
22            ELEC GENERATION (POINT)
23                 ANTHRACITE COAL
24                 BITUMINOUS COAL
25                 LIGNITE
26                 RESIDUAL OIL
27                 DISTILLATE OIL
28                 NATURAL GAS
29                 PROCESS GAS
30                 COKE
31                 BAGASSE
32                 SOLID WASTE/COAL
33                 OTHER
34                 TOTAL (ELEC GEN)
35            INDUSTRIAL FUEL
36                 ANTHRACITE COAL
37                      AREA SOURCES
38                      POINT SOURCES
39                 BITUMINOUS COAL
40                      AREA SOURCES
41                      POINT SOURCES
42                 LIGNITE
43                      POINT SOURCES
44                 RESIDUAL OIL
45                      AREA SOURCES
46                      POINT SOURCES
47                 DISTILLATE OIL
48                      AREA SOURCES
49                      POINT SOURCES
50                 NATURAL GAS
51                      AREA SOURCES
52                      POINT SOURCES
53                 PROCESS GAS
54                      AREA SOURCES
55                      POINT SOURCES
56                 COKE
57                      AREA SOURCES
58                      POINT SOURCES
59                 WOOD
60                      AREA SOURCES
```

1) Geographical Region

1. County & State name
2. State name
3. AQCR name
4. National summary

2) Pollutant

1. Particulates
2. Sulfur dioxide
3. Nitrogen oxides
4. Hydrocarbons
5. Carbon monoxide

Figure 4.1 Output format of NEDS reliability analysis.

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```
        61                   POINT SOURCES
        62               LIQUID PETROL GAS
        63                   POINT SOURCES
        64               BAGASSE
        65                   POINT SOURCES
        66               OTHER
        67                   POINT SOURCES
        68               TOTAL (INDUSTRIAL)
        69                   AREA SOURCES
        70                   POINT SOURCES
        71           COMM-INSTITUTIONAL FUEL
        72               ANTHRACITE COAL
        73                   AREA SOURCES
        74                   POINT SOURCES
        75               BITUMINOUS COAL
        76                   AREA SOURCES
        77                   POINT SOURCES
        78               LIGNITE
        79                   POINT SOURCES
        80               RESIDUAL OIL
        81                   AREA SOURCES
        82                   POINT SOURCES
        83               DISTILLATE OIL
        84                   AREA SOURCES
        85                   POINT SOURCES
        86               NATURAL GAS
        87                   AREA SOURCES
        88                   POINT SOURCES
        89               WOOD
        90                   AREA SOURCES
        91                   POINT SOURCES
        92               LIQUID PETROL GAS
        93                   POINT SOURCES
        94               OTHER
        95                   POINT SOURCES
        96               TOTAL (COMM-INST)
        97                   AREA SOURCES
        98                   POINT SOURCES
        99           OTHER (POINT)
       100           TOTAL (EXTERNAL COMB)
       101               AREA SOURCES
       102               POINT SOURCES
       103       INTERNAL COMBUSTION (POINT)
       104           ELECTRIC GENERATION
       105               DISTILLATE OIL
       106               NATURAL GAS
       107               DIESEL
       108               OTHER
       109               TOTAL (ELEC GEN)
       110           INDUSTRIAL FUEL
       111               DISTILLATE OIL
       112               NATURAL GAS
       113               GASOLINE
       114               DIESEL FUEL
       115               OTHER
       116               TOTAL (INDUSTRIAL)
       117           COMM-INSTITUTIONAL
       118               DIESEL
       119               OTHER
       120               TOTAL (COMM-INST)
[illegible]          ENGINE TESTING
```

Figure 4.1 (continued). Output format of NEDS reliability analysis.

```
122                 AIRCRAFT
123                 OTHER
124                 TOTAL (ENG TESTING)
125             OTHER (POINT)
126             TOTAL (STATIONAL COMP)
127         TOTAL (FUEL COMBUSTION)
128             AREA SOURCES
129             POINT SOURCES
130   INDUSTRIAL PROCESS (POINT)
131   **************************
132       CHEMICAL MANUFACTURING
133       FOOD/AGRICULTURAL
134       PRIMARY METAL
135       SECONDARY METALS
136       MINERAL PRODUCTS
137       PETROLEUM INDUSTRY
138       WOOD PRODUCTS
139       EVAPORATION
140       METAL FABRICATION
141       LEATHER PRODUCTS
142       TEXTILE MANUFACTURING
143       INPROCESS FUEL
144       OTHER/NOT CLASSIFIED
145       TOTAL (INDUSTRIAL)
146   SOLID WASTE DISPOSAL
147   ********************
148       GOVERNMENT (POINT)
149             MUNICIPAL INCINERATION
150             OPEN BURNING
151             OTHER
152             TOTAL (GOVERNMENT)
153       RESIDENTIAL (AREA)
154             ON SITE INCINERATION
155             OPEN BURNING
156             TOTAL (RESIDENTIAL)
157       COMMERCIAL-INSTITUTIONAL
158             ON SITE INCINERATION
159                   AREA SOURCES
160                   POINT SOURCES
161             OPEN BURNING
162                   AREA SOURCES
163                   POINT SOURCES
164             APARTMENT
165                   POINT SOURCES
166             OTHER
167                   POINT SOURCES
168             TOTAL (COMM-INST)
169                   AREA SOURCES
170                   POINT SOURCES
171       INDUSTRIAL
172             ON SITE INCINERATION
173                   AREA SOURCES
174                   POINT SOURCES
175             OPEN BURNING
176                   AREA SOURCES
177                   POINT SOURCES
178             AUTO BODY INCINERATION
179                   POINT SOURCES
180             RAIL CAR BURNING
181                   POINT SOURCES
182             OTHER
```

Figure 4.1 (continued). Output format of NEDS reliability analysis.

```
183                POINT SOURCES
184          TOTAL (INDUSTRIAL)
185                AREA SOURCES
186                POINT SOURCES
187      OTHER (POINT)
188      TOTAL (SOLID WASTE DISP)
189          AREA SOURCES
190          POINT SOURCES
191  TRANSPORTATION (AREA)
192  **********************
193      LAND VEHICLES
194          GASOLINE
195                LIGHT VEHICLES
196                HEAVY VEHICLES
197                OFF HIGHWAY
198                TOTAL (GASOLINE)
199          DIESEL
200                HEAVY VEHICLES
201                OFF HIGHWAY
202                RAIL
203                TOTAL (DIESEL)
204      AIRCRAFT
205          MILITARY
206          CIVIL
207          COMMERCIAL
208          TOTAL (AIRCRAFT)
209      VESSELS
210          ANTHRACITE (CAL)
211          DIESEL FUEL
212          RESIDUAL OIL
213          GASOLINE
214          TOTAL (VESSELS)
215      GAS HANDLING EVAP LOSS
216      TOTAL (TRANSPORTATION)
217  MISCELLANEOUS (AREA)
218  *********************
219      FOREST FIRE/AGRIC BURNING
220      STRUCTURAL FIRES
221      COAL REFUSE BURNING
222      SLASH BURNING
223      FROST CONTROL
224      SOLVENT EVAPORATION LOSS
225      DUST SOURCES
226          DIRT ROADS
227          DIRT AIRSTRIPS
228          CONSTRUCTION
229          ROCK HANDLING/STORING
230      TOTAL (MISCELLANEOUS)
231  OTHER (POINT)
232  *************
233  GRAND TOTAL
234  ***********
235      AREA SOURCES
236      POINT SOURCES
237      TOTAL
```

Figure 4.1 (continued). Output format of NEDS reliability analysis.

Section 4.5.3). Then, by indicating in SIEFA output the number of sources for which these approximate values are supplied, we are indicating also the degree of accuracy of the total emissions value. Stated very simply, we increase the overall accuracy of emissions reporting by substituting approximate values for missing data elements, and we indicate clearly the sources to which these approximate values are applied.

The user of SIEFA prepares a request card which specifies the geographical region and the pollutants to be inventoried.

Options for geographical area include:

1. One county
2. All counties in a state
3. One state
4. All states
5. One Air Quality Control Region (AQCR)
6. National Summary

The user may request an emissions inventory for one or more of the following pollutants;

1. Particulates
2. Sulfur dioxide
3. Nitrogen oxides
4. Hydrocarbons
5. Carbon monoxide

4.2 NEDS USER'S FILE

The NEDS user's file consists of fixed-length records, each containing 552 bytes. Figures 4.2 and 4.3 show the output formats for area and point source records, respectively. An area source record is identified by an A in position 9 and a point source by a P in position 9. For

AREA RECORD

Position	Format abbr.	Format defin.	Name
01-08	Reserved	x(8)	reserved for system use
09	'A'	X	defines area record
10-11	ST NO	99	State code
12-15	COUNTY	9999	County code
16-18	AQCR	999	AQCR number
19-32	BLANK	X(14)	spaces
33	NX	9	next record code
34-36	AQCR	999	AQCR number
37-38	YEAR	99	Year of record
39-43	EST.EMIS-PART	99999	Emission Estimate for Particulates (10^2 tons)
44-48	EST.EMIS-SO_2	99999	Emission Estimate for SO_2 (10^2 tons)
49-52	EST.EMIS-NO_x	9999	Emission Estimate for NO_x (10^2 tons)
53-57	EST.EMIS-HC	99999	Emission Estimate for HC (10^2 tons)
58-62	EST.EMIS-CO	99999	Emission Estimate for CO (10^2 tons)
63-64	SC-ANT	9V9	sulfur content for anthracite coal (%)
65-66	SC-BIT	9V9	sulfur content for bituminous coal (%)
67-68	SC-DO	9V9	sulfur content for distillate oil (%)
69-70	SC-RO	9V9	sulfur content for residual oil (%)
71-73	AC-ANT	99V9	ash content for anthracite coal (%)
74-76	AC-BIT	99V9	ash content for bituminous coal (%)

Figure 4.2 User emission file output, area record format.

77-80	RES FUEL-ANT	9999	residential fuel - anthracite coal (10 tons)
81-85	RES FUEL-BIT	99999	residential fuel - bituminous coal (10^1 tons)
86-90	RES FUEL-DO	99999	residential fuel - distillate oil (10^4 gallons)
91-95	RES FUEL-RO	99999	residential fuel - residual oil (10^4 gallons)
96-100	RES FUEL-GAS	99999	residential fuel - natural gas (10^7 cu. ft.)
101-104	RES FUEL-WD	9999	residential fuel - wood (10^2 tons)
105-109	C & I ANT	99999	commercial and institutional fuel - anthractie coal (10^1 tons)
110-114	C & I BIT	99999	commercial and institutional fuel - bituminous coal (10^1 tons)
115-119	C & I DIST	99999	commercial and institutional fuel - distillate oil (10^4 gallons)
120-124	C & I RESID	99999	commercial and institutional fuel - residual oil (10^4 gallons)
125-128	C & I GAS	9999	commercial and institutional fuel - natural gas (10^7 ft)
129-130	C & I WD	99	commercial and institutional fuel - wood (10^2 tons)
131-136	INDUS FUEL-ANT	999999	industrial fuel - anthracite coal (10^1 tons)
137-142	INDUS FUEL-BIT	999999	industrial fuel - bituminous coal (10^1 tons)
143-146	IND F - COKE	9999	industrial fuel - coke (10^1 tons)
147-151	IND FUEL-DIST	99999	industrial fuel - distillate oil (10^4 gallons)

Figure 4.2 (continued). User emission file output, area record format.

152-156	IND FUEL-RES	99999	industrial fuel - residual oil (10^4 gallons)
157-161	IND F - N G	99999	industrial fuel - natural gas (10^7 ft.^{3})
162-164	IF - WOOD	999	industrial fuel - wood (10^2 tons)
165-168	IF-P GAS	9999	industrial fuel - process gas (10^7 ft.^{3})
169-174	RESIDENTIAL OCI	999999	residential on site incineration (10^1 tons)
175-179	INDUSTRIAL OCI	99999	industrial on site incineration (10^2 tons)
180-183	C & I OCI	9999	commercial and institutional on site incineration (10^2 tons)
184-189	RESIDENTIAL OB	999999	residential open burning (10^2 tons)
190-195	INDUSTRIAL OB	999999	industrial open burning (10^2 tons)
196-201	C & I OB	999999	commercial and instutitional open burning (10^2 tons)
202-208	GAS FUEL-LT VEH	9999999	gasoline fuel - light vehicle (10^3 gallons)
209-213	GAS FUEL-HV VEH	99999	gasoline fuel-heavey vehicle (10^3 gallons)
214-218	GAS FUEL-OH	99999	gasoline fuel-off highway (10^3 gallons)
219-223	DIES FUEL-HV	99999	diesel fuel-heavy vehicle (10^3 gallons)
224-226	D F - OH	999	diesel fuel-off highway (10^4 gallons)
227-231	D F - RAIL	99999	diesel fuel - rail locomotive (10^4 gallons
232-235	CNTY POP	9999	county population (10^3)

Figure 4.2 (continued). User emission file output, area record format.

236	DEN	9	density code
237-240	MIL AIRC	9999	military aircraft-LTO cycles (10^2)
241-245	CIV AIRC	99999	civil aircraft-LTO cycles (10^1)
246-250	COMM AIRC	99999	commercial aircraft-LTO cycles (10^1)
251-254	VES F-ANT	9999	vessels-anthractie coal (10^1 tons)
255-258	VES F-DIES	9999	vessels-diesel oil (10^4 gallons)
259-263	VES F-RESID	99999	vessels-residual oil (10^4 gallons)
264-267	VES F-GAS	9999	vessels-gasoline (10^3 gallons)
268-273	EVAP SOLVENT	999999	evaporation-solvent purchased (tons/year)
274-278	EVAP GAS	99999	evaporation-gasoline marketed (10^3 gallons)
279-284	VEH MI-LAR	999999	measured vehicle miles-limited access roads (10^4 miles)
285-290	VEH MI-RUR RD	999999	measured vehicle miles-rural roads (10^4 miles)
291-296	VEH MI-SUR RD	999999	measured vehicle miles-suburban roads (10^4 miles)
297-303	VEH MI-URBAN RD	9999999	measured vehicle miles-urban roads (10^4 miles)
304-310	DIRT ROADS	9999999	dirt roads traveled (10^3 miles)
311-315	LTO-DIRT	99999	dirt air strips - LTO cycles
316-320	CONST AREA	99999	construction land area (10^3 acres)

Figure 4.2 (continued). User emission file output, area record format.

321-325	ROCK H&S	99999	rock handling and storing (10^3 tons)
326-332	FOR FIRES-AREA	9999999	forest fires area (acres)
333-335	FF-QU	999	forest fires quantity (tons/acre
336-341	SLASH BRN-AREA	999999	slash burning area (acres)
342-344	SB-SQ	999	slash burning quantity (tons/acre)
345-348	ORCH HTR	9999	frost control-orchard heaters (10^2)
349-351	DA FIR	99V9	frost control-days fired (days/year)
352-355	STRUCT FIR	9999	structure fires (#/year)
356-361	COAL REF BRN	999999	coal refuse burning-size of bank (10^2 yard^3)
362-364	CRB-#	9999	coal refuse burning-(#/year)
365-432	COMMENTS	x(67)	area source comments
433-442	PARTICULATE EMISSIONS	9(7)V999	particulate emissions (tons/year)
443-452	SO_2 EMISSIONS	9(7)V999	SO_2 emissions (tons/year)
453-462	NO_x EMISSIONS	9(7)V999	NO_x emissions (tons/year)
463-472	HC EMISSIONS	9(7)V999	HC emissions (tons/year)
473-482	CO EMISSIONS	9(7)V999	CO emissions (tons/year)
483-552	RESERVED	X(70)	reserved for up to seven additional pollutants

Figure 4.2 (continued). User emission file output, area record format.

POINT RECORD

Position	Format abbr.	Format defin.	Name
01-08	RESERVED	X(8)	reserved for system use
09	'P'	X	defines point record
10-11	ST NO	99	state code
12-15	COUNTY	9999	county code
16-18	'999'	XXX	9's filler
19-22	PLANT ID	9999	plant identification number
23-24	PT	99	point identification number
25-32	SCC CODE	99999999	source classification number
33	NX	9	next record code
34-36	AQCR	999	AQCR number
37-38	YR	99	year of record
39-42	CITY	9999	city code
43-44	UTM-Z	99	utm zone
45-84	ESTABLISHMENT NAME AND ADDRESS	X(40)	establishment name and address
85-96	PERSONAL CONTACT	X(12)	personal contact
97	O	X	ownership code
98-99	YR	99	year of record
100-103	SIC CODE	9999	standard industrial classification code
104-105	IPP PR	99	IPP process code
106-109	UTM-X	999V9	horizontal utm coordinate (km)
110-114	UTM-Y	9999V9	vertical utm coordinate (km)
115-118	STACK HT	9999	stack height (ft)
119-121	ST D	99V9	stack diameter (ft)

Figure 4.3 User emission file output, point record format.

122-125	STACK T	9999	stack temperature (°F)
126-132	FLOW RATE	9999999	flow rate (ft^3/min.)
133-136	PLUME HT	9999	plume height
137-138	MB-1	99	first multiple boiler code
139-140	MB-2	99	last multiple boiler code
141-142	YR	99	year of record
143-147	BOIL DES CAP	99999	boiler design capacity (10^6 BTU/hr)
148-150	C-E PAR1	999	primary control equipment particulates
151-153	C-E PAR2	999	secondary control equipment particulates
154-156	C-E $SO_2$1	999	primary control equipment SO_2
157-159	C-E $SO_2$2	999	secondary control equipment SO_2
160-162	C-E NO_x1	999	primary control equipment NO_x
163-165	C-E NO_x2	999	secondary control equipment NO_x
166-168	c-E HC1	999	primary control equipment HC
169-171	C-E HC2	999	secondary control equipment HC
172-174	C-E CO1	999	primary control equipment CO
175-177	C-E CO2	999	secondary control equipment CO
178-180	ECE-PAR	99V9	estimated control efficiency particulates (%)
181-183	ECE-SO_2	99V9	estimated control efficiency SO_2 (%)
184-186	ECE-NO_x	99V9	estimated control efficiency NO_x (%)
187-189	ECE-HC	99V9	estimated control efficiency HC (%)
190-192	ECE-CO	99V9	estimated control efficiency CO (%)

Figure 4.3 (continued). User emission file output, point record format.

193-194	YR	99	year of record
195-196	%WIN	99	% annual thruput (Dec-Feb)
197-198	%SPG	99	% annual thruput (Mar-May)
199-200	%SUM	99	% annual thruput (June-Aug)
201-202	%FAL	99	% annual thruput (Sept-Nov)
203-204	HR/DA	99	normal operating hours per day
205	D/W	9	normal operating hours per week
206-207	WK/YR	99	normal operating weeks per year
208-214	EMIS EST-PAR	9999999	estimated emissions-particulates (tons/year)
215-221	EMIS EST-SO_2	9999999	estimated emissions-SO_2 (tons/year)
222-228	EMIS EST-NO_x	9999999	estimated emissions-NO_x (tons/year)
229-235	EMIS EST-HC	9999999	estimated emissions-HC (tons/year)
236-242	EMIS EST-CO	9999999	estimated emissions-CO (tons/year)
243	EMP	9	estimation method-Particulates
244	EMS	9	estimation method-SO_2
245	EMN	9	estimation method-NO_x
246	EMH	9	estimation method HC
247	EMC	9	estimation method CO
248-250	% SP HT	99V9	% space heat
251-252	YR	99	year of record
253-259	ALLOW EMIS-PAR	9999999	allowable emissions-particulates (tons/year)

Figure 4.3 (continued). User emission file output, point record format.

260-266	ALLOW EMIS-SO_2	9999999	allowable emissions-SO_2 (tons/year)
267-273	ALLOW EMIS-NO_x	9999999	allowable emissions-NO_x (tons/year)
274-280	ALLOW EMIS-HC	9999999	allowable emissions-HC (tons/year)
281-287	ALLOW EMIS-CO	9999999	allowable emissions-CO (tons/year)
288	CS	9	compliance status
289-290	CS-YR	99	compliance schedule-year
291-292	CS-MO	99	compliance schedule-month
293-294	CSU-Y	99	compliance status update-year
295-296	CSU-M	99	compliance status update-month
297-298	CSU-D	99	compliance status update-day
299	E	9	emergency control action program status
300-303	REG 1	XXXX	control regulation #1
304-307	REG 2	XXXX	control regulation #2
308-311	REG 3	XXXX	control regulation #3
312-313	YR	99	year of record
314-320	OPERATING RATE	9999999	fuel, process, solid waste operating rate
321-327	MAX DESIGN RATE	9999V999	maximum design rate
328-330	SUL CONT	9V99	% sulfur content
331-333	ASH CONT	99V9	% ash content
334-338	HEAT CONTENT	99999	heat content (10^6 btu)
339-358	COMMENTS	X(20)	comments
359	S	X	source code

Figure 4.3 (continued). User emission file output, point record format.

360	C	9	confidentiality of data
361-432	BLANK	X(72)	spaces
433-442	PARTICULATE EMISSIONS	9(7)V999	particulate emissions (tons/year)
443-452	SO_2 EMISSIONS	9(7)V999	SO_2 emissions (tons/year)
453-462	NO_x EMISSIONS	9(7)V999	NO_x emissions (tons/year)
463-472	HC EMISSIONS	9(7)V999	HC emissions (tons/year)
473-482	CO EMISSIONS	9(7)V999	CO emissions (tons/year)
483-552	RESERVED	X(70)	reserved for up to seven additional pollutants

Figure 4.3 (continued). User emission file output, point record format.

each county there is one area source record followed by a number of point source records, which are in sequence by plant ID number and point ID within each plant. When a point ID has more than one source classification code (SCC), the records are in sequence by SCC.

The first record for a state is a dummy record containing the State ID number in positions 10-11 and zeros in positions 12-32. The last record in the user file is also a dummy record with a 99 for State ID.

4.3 DATA SELECTION

The user's request card specifies the geographical area and pollutant(s) to be inventoried. The basic output tabulation provides an inventory of all area and point source emissions of a single pollutant in a county. If the inventory is to include more than one pollutant, the system outputs data for one pollutant at a time.

When the retrieval strategy requires an inventory for a number of counties, as for example when the user wishes to inventory all counties in a state, the system processes each county in sequence from the NEDS User File. If the retrieval strategy requires an accumulation of data for a number of counties, as for example an inventory of an AQCR or a state or national summary, the system sets up a selection key appropriate for the geographical area. The area and point source data required for the output are accumulated and the totals are printed after data for the last county have been processed. Because of the amount of output and computer time, it would be unwise to request a run for each county in the entire United States. Such a project should be handled as a series of inventories of individual states.

Having determined the first county to be included in the inventory, the system reads the first record for the county. This first record should have an A in position 9 of the record, signifying data for area sources in the county. Each successive record should have a P in position 9, signifying data for an individual point source.

4.4 PROCEDURE FOR CALCULATION OF AREA SOURCE DATA

The program calculates estimated annual emissions and the variance of the annual emissions value for each area source category identified by Source Type A on Figure 4.4. The equation for determining estimated annual emissions is:

$$E = \frac{MTF}{2000}$$

where E = Estimated annual emissions (tons/year)

M = Multiplier to maintain units of measurement (see Table 4.1).

T = Annual thruput (see Figure 4.4 for position in record).

F = Emission factor

Note: Emission factors for area sources are given in Table 4.1. Emission factors are related to the specific area source by the appropriate line number on the output listing. When the pollutant being inventoried is either par-

Source Type	Line No.		Point Source SCC			Area Source (Position in Record)		
			I	II	III	Sulfur Content %	Ash Content %	Thruput
	1							
	2							
	3							
	4							
	5							
	6							
	7							
	8							
	9							
	10							
	11	**FUEL COMBUSTION**						
	12	********************						
	13	EXTERNAL COMBUSTION						
	14	RESIDENTIAL FUEL (AREA)						
A	15	ANTHRACITE COAL				63-64	-	77-80
A	16	BITUMINOUS COAL				65-66	-	81-85
A	17	DISTILLATE OIL				67-68	-	86-90
A	18	RESIDUAL OIL				69-70	-	91-95
A	19	NATURAL GAS				-	-	96-100
A	20	WOOD				-	-	101-104
A	21	TOTAL (RESIDENTIAL)						
	22	ELEC GENERATION (POINT)						
P	23	ANTHRACITE COAL	1	01	001			
P	24	BITUMINOUS COAL	1	01	002			
P	25	LIGNITE	1	01	003			
P	26	RESIDUAL OIL	1	01	004			
P	27	DISTILLATE OIL	1	01	005			
P	28	NATURAL GAS	1	01	006			
P	29	PROCESS GAS	1	01	007			
P	30	COKE	1	01	008			
P	31	BAGASSE	1	01	011			
P	32	SOLID WASTE/COAL	1	01	012			
P	33	OTHER	1	01	099			
P	34	TOTAL (ELEC GEN)	1	01				

Figure 4.4 Selected categories for point source SCC's and area source position in record.

						(Area Source)		
Source Type	Line No.		Point Source SCC			Sulfur Content %	Ash Content %	Thruput
			I	II	III			
	35	INDUSTRIAL FUEL						
	36	ANTHRACITE COAL						
A	37	AREA SOURCES				63-64	71-73	131-136
P	38	POINT SOURCES	1	02	001			
	39	BITUMINOUS COAL						
A	40	AREA SOURCES				65-66	74-76	137-142
P	41	POINT SOURCES	1	02	002			
	42	LIGNITE						
P	43	POINT SOURCES	1	02	003			
	44	RESIDUAL OIL						
A	45	AREA SOURCES				67-68	-	152-156
P	46	POINT SOURCES	1	02	004			
	47	DISTILLATE OIL						
A	48	AREA SOURCES				69-70	-	147-151
P	49	POINT SOURCES	1	02	005			
	50	NATURAL GAS						
A	51	AREA SOURCES				-	-	157-161
P	52	POINT SOURCES	1	02	006			
	53	PROCESS GAS						
A	54	AREA SOURCES				-	-	165-168
P	55	POINT SOURCES	1	02	007			
	56	COKE						
A	57	AREA SOURCES				0	-	143-146
P	58	POINT SOURCES	1	02	008			
	59	WOOD						
A	60	AREA SOURCES				-	-	162-164
P	61	POINT SOURCES	1	02	009			
	62	LIQUID PETROL GAS						
P	63	POINT SOURCES	1	02	010			
	64	BAGASSE						
P	65	POINT SOURCES	1	02	011			
	66	OTHER						
P	67	POINT SOURCES	1	02	999			
	68	TOTAL (INDUSTRIAL)						
A	69	AREA SOURCES						
P	70	POINT SOURCES	1	02				

Figure 4.4 (continued). Selected categories for print source SCC's and area source position in record.

Source Type	Line No.		Point Source SCC			(Area Source)		
			I	II	III	Sulfur Content %	Ash Content %	Thruput
	71	COMM-INSTITUTIONAL FUEL						
	72	ANTHRACITE COAL						
A	73	AREA SOURCES				63-64	71-73	105-109
P	74	POINT SOURCES	1	03	001			
	75	BITUMINOUS COAL						
A	76	AREA SOURCES				65-66	74-76	110-114
P	77	POINT SOURCES	1	03	002			
	78	LIGNITE						
P	79	POINT SOURCES	1	03	003			
	80	RESIDUAL OIL						
A	81	AREA SOURCES				67-68	-	120-124
P	82	POINT SOURCES	1	03	004			
	83	DISTILLATE OIL						
A	84	AREA SOURCES				69-70	-	115-119
P	85	POINT SOURCES	1	03	005			
	86	NATURAL GAS						
A	87	AREA SOURCES				-	-	125-128
P	88	POINT SOURCES	1	03	006			
	89	WOOD						
A	90	AREA SOURCES				-	-	129-130
P	91	POINT SOURCES	1	03	009			
	92	LIQUID PETROL GAS						
P	93	POINT SOURCES	1	03	010			
	94	OTHER						
P	95	POINT SOURCES	1	03	999			
	96	TOTAL (COMM-INST)						
A	97	AREA SOURCES						
P	98	POINT SOURCES	1	03				
	99	OTHER (POINT)	-	-	-			
	100	TOTAL (EXTERNAL COMB)						
A	101	AREA SOURCES						
P	102	POINT SOURCES	1					
	103	INTERNAL COMBUSTION (POINT)						
	104	ELECTRIC GENERATION						
P	105	DISTILLATE OIL	2	01	001			
P	106	NATURAL GAS	2	01	002			

Figure 4.4 (continued). Selected categories for print source SCC's and area source position in record.

Source Type	Line No.		Point Source SCC I	Point Source SCC II	Point Source SCC III	(Area Source) Sulfur Content %	(Area Source) Ash Content %	(Area Source) Thruput
P	107	DIESEL	2	01	003			
P	108	OTHER	2	01	999			
P	109	TOTAL (ELEC GEN)	2	01				
	110	INDUSTRIAL FUEL						
P	111	DISTILLATE OIL	2	02	001			
P	112	NATURAL GAS	2	02	002			
P	113	GASOLINE	2	02	003			
P	114	DIESEL FUEL	2	02	004			
P	115	OTHER	2	02	999			
P	116	TOTAL (INDUSTRIAL)	2	02				
	117	COMM-INSTITUTIONAL						
P	118	DIESEL	2	03	001			
P	119	OTHER	2	03	999			
P	120	TOTAL (COMM-INST)	2	03				
	121	ENGINE TESTING						
P	122	AIRCRAFT	2	04	001			
P	123	OTHER	-	-	-			
P	124	TOTAL (ENG TESTING)	2	04				
P	125	OTHER (POINT)	-	-	-			
P	126	TOTAL (INTERNAL COMB)	2					
	127	TOTAL (FUEL COMBUSTION)						
A	128	AREA SOURCES						
P	129	POINT SOURCES	≤2					
	130	INDUSTRIAL PROCESS (POINT)						
	131	**************************						
P	132	CHEMICAL MANUFACTURING	3	01				
P	133	FOOD/AGRICULTURAL	3	02				
P	134	PRIMARY METAL	3	03				
P	135	SECONDARY METALS	3	04				
P	136	MINERAL PRODUCTS	3	05				
P	137	PETROLEUM INDUSTRY	3	06				
P	138	WOOD PRODUCTS	3	07				
P	139	EVAPORATION *	3	08				
P	140	METAL FABRICATION	3	09				

* SCC 4 XX XXX XX = 3 08

Figure 4.4 (continued). Selected categories for point source SCC's and area source position in record.

						(Area Source)		
Source Type	Line No.		Point Source SCC			Sulfur Content	Ash Content	Thruput
			I	II	III	%	%	
P	141	LEATHER PRODUCTS	3	20				
P	142	TEXTILE MANUFACTURING	3	30				
P	143	INPROCESS FUEL	3	90				
P	144	OTHER/NOT CLASSIFIED	3	99				
P	145	TOTAL (INDUSTRIAL)	3					
	146	SOLID WASTE DISPOSAL						
	147	********************						
	148	GOVERNMENT (POINT)						
P	149	MUNICIPAL INCINERATION	5	01	001			
P	150	OPEN BURNING	5	01	002			
P	151	OTHER	5	01	005			
P	152	TOTAL (GOVERNMENT)	5	01				
	153	RESIDENTIAL (AREA)						
A	154	ON SITE INCINERATION						169-174
A	155	OPEN BURNING						184-189
A	156	TOTAL (RESIDENTIAL)						
	157	COMMERCIAL-INSTITUTIONAL						
	158	ON SITE INCINERATION						
A	159	AREA SOURCES						180-183
P	160	POINT SOURCES	5	02	001			
	161	OPEN BURNING						
A	162	AREA SOURCES						196-201
P	163	POINT SOURCES	5	02	002			
	164	APARTMENT						
P	165	POINT SOURCES	5	02	003			
	166	OTHER						
P	167	POINT SOURCES	5	02	005			
	168	TOTAL (COMM-INST)						
A	169	AREA SOURCES						
P	170	POINT SOURCES	5	02				
	171	INDUSTRIAL						
	172	ON SITE INCINERATION						
A	173	AREA SOURCES						175-179
P	174	POINT SOURCES	5	03	001			
	175	OPEN BURNING						
A	176	AREA SOURCES						190-195
P	177	POINT SOURCES	5	03	002			

Figure 4.4 (continued). Selected categories for point source SCC's and area source position in record.

Source Type	Line No.		Point Source SCC			(Area Source)		
			I	II	III	Sulfur Content %	Ash Content %	Thruput
	178	AUTO BODY INCINERATION						
P	179	POINT SOURCES	5	03	003			
	180	RAIL CAR BURNING						
P	181	POINT SOURCES	5	03	004			
	182	OTHER						
P	183	POINT SOURCES	5	03	005			
	184	TOTAL (INDUSTRIAL)						
A	185	AREA SOURCES						
P	186	POINT SOURCES	5	03				
	187	OTHER (POINT)	-	-	-			
	188	TOTAL (SOLID WASTE DISP)						
A	189	AREA SOURCES						
P	190	POINT SOURCES	5					
	191	TRANSPORTATION (AREA)						
	192	**********************						
	193	LAND VEHICLES						
	194	GASOLINE						
A	195	LIGHT VEHICLES - SEE PROCEDURE FOR MOTOR VEHICLES - PROCEDURE A						
A	196	HEAVY VEHICLES - SEE PROCEDURE FOR MOTOR VEHICLES - PROCEDURE A						
A	197	OFF HIGHWAY SEE PROCEDURE C						214-218
A	198	TOTAL (GASOLINE)						
	199	DIESEL						
A	200	HEAVY VEHICLES - SEE PROCEDURE FOR MOTOR VEHICLES - PROCEDURE A						
A	201	OFF HIGHWAY						224-226
A	202	RAIL						227-231
A	203	TOTAL (DIESEL)						
	204	AIRCRAFT						
A	205	MILITARY						237-240
A	206	CIVIL						241-245
A	207	COMMERCIAL						246-250
A	208	TOTAL (AIRCRAFT)						
	209	VESSELS						
A	210	ANTHRACITE COAL						251-254
A	211	DIESEL FUEL						255-258
A	212	RESIDUAL OIL						259-263
A	213	GASOLINE						264-267

Figure 4.4 (continued). Selected categories for point source SCC's and area source position in record.

Source Type	Line No.		Point Source SCC I	II	III	(Area Source) Sulfur Content %	Ash Content %	Thruput
A	214	TOTAL (VESSELS)						
A	215	GAS HANDLING EVAP LOSS						274-278
A	216	TOTAL (TRANSPORTATION)						
	217	MISCELLANEOUS (AREA)						
	218	*********************						
A	219	FOREST FIRE/AGRIC BURNING	SEE PROCEDURE B					326-332
A	220	STRUCTURAL FIRES						352-355
A	221	COAL REFUSE BURNING	SEE PROCEDURE B					356-361
	222	SLASH BURNING	SEE PROCEDURE B					336-341
A	223	FROST CONTROL	SEE PROCEDURE B					345-348
A	224	SOLVENT EVAPORATION LOSS						268-273
	225	DUST SOURCES						
A	226	DIRT ROADS						304-310
A	227	DIRT AIRSTRIPS						311-315
A	228	CONSTRUCTION						316-320
A	229	ROCK HANDLING/STORING						321-325
A	230	TOTAL (MISCELLANEOUS)						
	231	OTHER (POINT)						
	232	**************						
	233	GRAND TOTAL						
	234	************						
A	235	AREA SOURCES a						
P	236	POINT SOURCES b						
	237	TOTAL						
		a. ALL AREA SOURCES						
		b. ALL POINT SOURCES (line 129, 145, 190)						
		c. a + b						

Figure 4.4 (continued). Selected categories for point source SCC's and area source position in record.

Table 4.1. **AREA SOURCE EMISSION FACTORS**

Line No. on output	Category	Emission factor					
		Mult.	Part.	SO_x	NO_x	HC	CO
15	ANTH. COAL-RES	10	10.000	36.000S	3.000	2.500	90.000
16	BIT. COAL-RES.	10	20.000	38,000S	3.000	20.000	90.000
17	DIST. OIL-RES.	10	10.000	142.000S	12.000	3.000	5.000
18	RESID. OIL-RES.	10	23.000	157.000S	40.000	3.000	0.200
19	NAT. GAS-RES.	10	19.000	0.600	50.000	8.000	20.000
20	WOOD-RES.	100	25.000	0.500	10.000	2.000	2.000
37	ANTH. COAL-IND.	10	2.000A	38.000S	15.000	0.200	2.000
40	BIT. COAL-IND.	10	13.000A	38.000S	15.000	1.000	2.000
45	RESID. OIL-IND.	10	23.000	157.000S	60.000	3.000	0.200
48	DIST. OIL-IND.	10	15.000	142.000S	60.000	3.000	0.200
51	NAT. GAS-IND.	10	18.000	0.600	180.000	40.000	0.400
54	PROC. GAS-IND.	10	18.000	N/A	230.000	40.000	0.400
57	COKE-IND.	10	NYD	NYD	NYD	NYD	NYD
60	WOOD-IND.	100	25.000	0.500	10.000	2.000	2.000
73	ANTH. COAL-C&I	10	2.000A	38.000S	10.000	0.200	6.000
76	BIT. COAL-C&I	10	5.800A	38.000S	9.200	2.000	7.200
81	RESID. OIL-C&I	10	23.000	157.000S	60.000	3.000	0.200
84	DIST. OIL-C&I	10	15.000	142.000S	60.000	3.000	0.200
87	NAT. GAS-C&I	10	19.000	0.600	100.000	8.000	20.000
90	WOOD-C&I	100	25.000	0.500	10.000	2.000	2.000
154	INCIN. ON SITE-RES.	10	30.000	0.500	1.000	100.000	300.000
155	OPEN BURN-RES.	100	16.000	1.000	6.000	34.000	85.000
159	INCIN. ON SITE-C&I	100	12.000	1.500	2.000	10.000	20.000
162	OPEN BURN-C&I	100	16.000	1.000	6.000	34.000	85.000

Table 4.1. (continued). **AREA SOURCE EMISSION FACTORS**

Line No. on output	Category	Mult.	Part.	SO_x	NO_x	HC	CO
173	INCIN. ON SITE-IND.	100	12.000	1.500	2.000	10.000	20.000
176	OPEN BURN-IND.	100	16.000	1.000	6.000	34.000	85.000
195	LIGHT VEH. GASOLINE		SEE PROCEDURE A				
196	HEAVY VEH. GASOLINE		SEE PROCEDURE A				
197	OFF HIGHWAY GASOLINE	1	8.000	5.000	176.000	553.000	3030.000
200	HEAVY VEH. DIESEL		SEE PROCEDURE A				
201	OFF HIGHWAY DIESEL	10	13.000	27.000	370.000	37.000	225.000
202	RAIL DIESEL	10	25.000	65.000	75.000	50.000	70.000
205	MILITARY AIRCRAFT	100	19.900	3.800	9.560	46.300	49.700
206	CIVIL AIRCRAFT	10	0.569	0.113	0.514	2.520	14.400
207	COMMERCIAL AIRCRAFT	10	19.500	4.320	12.200	46.000	111.000
210	BIT. COAL VESSELS	10	20.000	50.000	3.000	20.000	90.000
211	DIESEL FUEL VESSELS	10	25.000	65.000	75.000	50.000	70.000
212	RESID. OIL VESSELS	10	23.000	100.000	60.000	3.000	0.200
213	GASOLINE VESSELS	1	8.000	5.000	175.000	553.000	3030.000
215	GASOLINE HAND. EVAP.	100	0.000	0.000	0.000	21.000	0.000
219	FOREST FIRES, ETC.	Quan.	NYD	NYD	NYD	NYD	NYD
220	STRUCTURAL FIRES	1	NYD	NYD	NYD	NYD	NYD
221	COAL REFUSE BURNING	100 x Quan.	NYD	NYD	NYD	NYD	NYD
222	SLASH BURNING	Quan.	17.000	0.000	2.000	20.000	60.000
223	FROST CONTROL	Days Fir	NYD	NYD	NYD	NYD	NYD
224	SOLVENT EVAP. LOSS	1	0.000	0.000	0.000	2000.000	0.000

Table 4.1. (continued). AREA SOURCE EMISSION FACTORS

Line No. on output	Category	Mult.	Part.	SO_x	NO_x	HC	CO
226	DIRT ROADS DUST	1	NYD	0.000	0.000	0.000	0.000
227	DIRT AIRSTRIP DUST	1	NYD	0.000	0.000	0.000	0.000
228	CONSTRUCTION DUST	1	NYD	0.000	0.000	0.000	0.000
229	ROCK HANDLING DUST	1	NYD	0.000	0.000	0.000	0.000

NYD = Emission factor not yet defined

ticulates or SO_x the emission factor may contain a suffix of A (ash) or S (sulfur) content.

Line No.	A	S
15		X
16		X
17		X
18		X
37	X	X
40	X	X
45		X
48		X
73	X	X
76	X	X
81		X
84		X

The position of sulfur content and ash content values for each fuel type is presented in Figure 4.2.

If the emission factor is blank, estimated annual emissions and variance of estimated annual emissions are also blank.

Note: If the value for thruput, or ash or sulfur content where applicable, is blank in the User's File, estimated annual emissions and variance of annual emissions are blank.

The equation for determining variance of estimated emissions is:

$$\mathrm{Var}\ (E) = E^2\ [(P_t)^2 + (P_f)^2 + (P_c)^2]$$

where E = estimated annual emissions
P_t = precision of thruput (Table 4.2)
P_f = precision of emission factor (Table 4.3)
P_c = precision of ash (A) or sulfur (S)

Note: If pollutant is particulates,

$$P_c = \frac{N}{A}$$

where $N = 0.5$ if $A \leq 12.0$
$N = 1.0$ if $A > 12.0$
If $A = 0$ $P_c = 0$

Note: If pollutant is sulfur dioxide and line No. is 15, 16, 37, 40, 73, 76

$$Pc = \frac{M}{S}$$

where $M = 0.1$ if $S \leq 2.00$
$M = 0.2$ if $S > 2.00$
If $S = 0$ $P_c = 0$

Note: If pollutant is sulfur dioxide and line No. is 17, 18, 45, 48, 81, 84

$$P_c = \frac{M}{S}$$

where $M = 0.03$ If $S \leq 0.50$
$M = 0.04$ $0.50 < S \leq 1.00$
$M = 0.05$ $1.00 < S \leq 2.00$
$M = 0.07$ $2.00 < S \leq 3.00$

Table 4.2. PRECISION OF THRUPUTS FOR AREA SOURCES

Line No. on Output	Category	P_t	Comments
15	ANTH. COAL-RES.	0.196	(for a zero in Position 81-85)
		0.045	(for an entry or blank in Position 81-85)
16	BIT. COAL-RES.	0.196	(for a zero in Position 77-80)
		0.045	(for an entry or blank in Position 77-80)
17	DIST. OIL-RES.	0.104	
18	RESID. OIL-RES.	0.144	
19	NAT. GAS-RES.	0.054	
20	WOOD-RES.	0.555	
37	ANTH. COAL-IND.	0.664	
40	BIT. COAL-IND.	$1.26 \times 10^2 \text{ (entry)}^{-.97}$	
45	RESID. OIL-IND.	0.023	
48	DIST. OIL-IND.	0.023	
51	NAT. GAS-IND.	0.127	
54	PROC. GAS-IND.	0.200	
57	COKE-IND.	0.150	
60	WOOD-IND.	0.250	
73	ANTH. COAL-C&I	0.615	(for a zero in Position 131-136)
		0.637	(for an entry or blank in Position 131-136)
76	BIT. COAL-C&I	0.294	
81	RESID. OIL-C&I	0.144	
84	DIST. OIL-C&I	0.312	
87	NAT. GAS-C&I	0.050	
90	WOOD-C&I	0.269	
154	INCIN. ON SITE-RES.	10.00	
155	OPEN BURN.-RES.	10.00	
159	INCIN. ON SITE-C&I	10.00	
162	OPEN BURN.-C&I	10.00	
173	INCIN. ON SITE-IND.	10.00	

Table 4.2. (continued). PRECISION OF THRUPUTS FOR AREA SOURCES

Line No. on output	Category	P_t	Comments
176	OPEN BURN-IND.	10.00	
195	LIGHT VEH. GASOLINE	-	Use Procedure A
196	HEAVY VEH. GASOLINE	-	Use Procedure A
197	OFF HIGHWAY GASOLINE	-	Use Procedure C
200	HEAVY VEH. DIESEL	-	Use Procedure A
201	OFF HIGHWAY DIESEL	0.082	
202	RAIL DIESEL	0.100	
205	MILITARY AIRCRAFT	0.5/LTO x 10^2	(i.e. 0.5/entry)
206	CIVIL AIRCRAFT	0.5/LTO x 10^1	
207	COMMERCIAL AIRCRAFT	0.5/LTO x 10^1	
210	ANTH. COAL VESSELS	0.030	
211	DIESEL FUEL VESSELS	0.130	
212	RESID. OIL VESSELS	0.180	
213	GASOLINE VESSELS	0.158	
215	GASOLINE HAND. EVAP.	0.060	
219	FOREST FIRES, ETC.	-	Use Procedure B
220	STRUCTURAL FIRES	5/# per year	
221	COAL REFUSE BURNING	-	Use Procedure B
222	SLASH BURNING	-	Use Procedure B
223	FROST CONTROL	-	Use Procedure B
224	SOLVENT EVAP. LOSS	*	
226	DIRT ROADS DUST	0.503	
227	DIRT AIRSTRIP DUST	0.000	
228	CONSTRUCTION DUST	0.5/acres x 10^3	
229	ROCK HANDLING DUST	0.5/tons x 10^3	

* Precision is dependent upon population

$P_t = 0.32$ if population < 100,000

$P_t = 0.41$ if population 100,000 - 499,000

$P_t = 0.06$ if population 500,000 - 1,000,000

$P_t = 0.05$ if population >1,000,000

Table 4.3 PRECISION OF AREA SOURCE UNIT EMISSION FACTORS

Category	Output line no.	Pollutant				
		Particulate	SO_2	NO_x	HC	CO
Anthracite Coal						
Residential	15	0.211	0.146	0.172	0.237	0.357
Commercial/Inst.	73	0.211	0.146	0.172	0.237	0.357
Industrial	37	0.211	0.146	0.172	0.237	0.357
Bituminous Coal						
Residential	16	0.211	0.146	0.172	0.237	0.357
Commercial/Inst.	76	0.132	0.254	0.700	0.237	0.357
Industrial	40	0.132[a]	0.254[a]	0.700[a]	0.237	0.357
Distillate Oil						
Residential	17	0.211	0.146	0.172	0.237	0.357
Commercial/Inst.	84	0.211	0.146	0.172	0.237	0.357
Industrial	48	0.211	0.146	0.172	0.237	0.357
Residual Oil						
Residential	18	0.211	0.027	0.003	0.237	0.357
Commercial/Inst.	81	0.211	0.027	0.003	0.237	0.357
Industrial	45	0.211	0.027	0.003	0.237	0.357

a) Priority area source.

Table 4.3 (continued). PRECISION OF AREA SOURCE UNIT EMISSION FACTORS

Category	Output line no.	Pollutant				
		Particulate	SO_2	NO_x	HC	CO
Natural Gas						
Residential	19	0.211	0.146	0.187	0.237	0.357
Commercial/Inst.	87	0.211	0.146	0.187	0.237	0.357
Industrial	51	0.211	0.146	0.391[a]	0.237	0.357
Wood - all categories	20,60,90	0.211	0.146	0.172	0.237	0.357
Process Gas-Indus.	54	0.211	0.146	0.391	0.237	0.357
On-Site Incineration						
Residential	154	0.211	0.146	0.172	0.237	0.357
Commercial	159	0.211	0.146	0.172	0.237	0.357
Industrial	173	0.211	0.146	0.172	0.237	0.357
Open Burning						
Residential	155	0.211	0.146	0.172	0.237	0.357
Commercial	162	0.211	0.146	0.172	0.237	0.357
Industrial	176	0.211	0.146	0.172	0.237	0.357
Evaporation						
Solvent	224	--	--	--	0.000[a]	--

a) Priority area source.

Table 4.3 (continued). PRECISION OF AREA SOURCE UNIT EMISSION FACTORS

Category	Output line no.	Pollutant				
		Particulate	SO_2	NO_x	HC	CO
Evaporation (cont'd.)						
Gasoline marketing	215	--	--	--	0.921[a]	--
Dirt Roads	226	NYD	--	--	--	--
Dirt Airstrips	227	NYD	--	--	--	--
Construction	228	NYD	--	--	--	--
Rock Handling & Storage	229	NYD	--	--	--	--
Forest Fires	219	NYD	NYD	NYD	NYD	NYD
Slash Burning	222	0.208	--	0.172	0.237	0.357
Frost Control	223	NYD	NYD	NYD	NYD	NYD
Structure Fires	220	NYD	NYD	NYD	NYD	NYD
Coal Refuse Burning	221	NYD	NYD	NYD	NYD	NYD
Off Highway						
Gasoline	197	0.211	0.146	0.172	0.044[a]	0.028[a]
Diesel	201	0.211	0.146	0.172	0.237	0.357
Rail Locomotive	202	0.211	0.146	0.172	0.237	0.357

a) Priority area source.
NYD = Emission factor not yet defined.

Table 4.3 (continued). PRECISION OF AREA SOURCE UNIT EMISSION FACTORS

Category	Output line no.	Pollutant				
		Particulate	SO_2	NO_x	HC	CO
Aircraft						
Military	205	0.211	0.146	0.172	0.237	0.357
Civil	206	0.211	0.146	0.172	0.237	0.357
Commercial	207	0.211	0.146	0.172	0.237	0.357
Vessels						
Bituminous coal	210	0.211	0.146	0.172	0.237	0.357
Distillate oil	211	0.211	0.146	0.172	0.237	0.357
Residual oil	212	0.211	0.146	0.172	0.237	0.357
Gasoline	213	0.211	0.146	0.172	0.237	0.357
Coke - Industrial	57	NYD	NYD	NYD	NYD	NYD
Vehicles						
Light-duty gasoline	195		See Procedure A			
Heavy-duty gasoline	196		See Procedure A			
Heavy-duty diesel	200		See Procedure A			

NYD = Emission factor not yet defined.

$M = 0.09$ $\quad 3.00 < S \leq 4.00$

$M = 0.12$ $\quad 4.00 < S \leq 5.00$

$M = 0.14$ $\quad S \geq 5.00$

If $\quad S = 0 \quad P_c = 0$

4.4.1 Procedure A

Procedure for determining motor vehicle emissions (lines 195, 196 and 200) is as follows:

Read data for fuel usage and measured vehicle miles.

Position	Format abbr.	Variable	Format def.	Name
202-208	GAS FUEL-LT VEH	G_1	9999999	gasoline fuel-light vehicle (10^3 gallons)
209-213	GAS FUEL-HV VEH	G_2	99999	gasoline fuel-heavy vehicle (10^3 gallons)
219-223	DIES FUEL-HV	G_3	99999	diesel fuel-heavy vehicle (10^3 gallons)
279-284	VEH MI-LAR	M_1	999999	measured vehicle miles-limited access roads (10^4 miles)
285-290	VEH MI-RUR RD	M_2	999999	measured vehicle miles-rural roads (10^4 miles)
291-296	VEH MI-SUR RD	M_3	999999	measured vehicle miles-subruban roads (10^4 miles)
297-303	VEH MI-URBAN RD	M_4	9999999	measured vehicle miles-urban roads (10^4 miles)

If G_1, G_2, G_3, M_1, M_2, M_3, M_4 are all zero or blank, put blanks in lines 195, 196 and 200 on output for both estimated total emissions and standard deviation of emissions and go on to next category.

If G_1, G_2, G_3 all greater than zero calculate

1. $M_{LV\cdot G} = (1000)(13.6)\ G_1$
2. $M_{HV\cdot G} = (1000)(8.4)\ G_2$
3. $M_{HV\cdot D} = (1000)(5.0)\ G_3$
4. $M_T = M_{LV\cdot G} + M_{HV\cdot G} + M_{HV\cdot D}$
5. $R_{LV\cdot G} = \dfrac{M_{LV\cdot G}}{M_T}$
6. $R_{HV\cdot G} = \dfrac{M_{HV\cdot G}}{M_T}$
7. $R_{HV\cdot D} = \dfrac{M_{HV\cdot D}}{M_T}$

If M_1, M_2, M_3, M_4 are all ≥ 0

8. $S_{LV\cdot G} = [M_1F_{11} + M_2F_{21} + M_3F_{31} + M_4F_{41}]$
9. $S_{HV\cdot G} = [M_1F_{12} + M_2F_{22} + M_3F_{32} + M_4F_{42}]$
10. $S_{HV\cdot D} = [M_1F_{13} + M_2F_{23} + M_3F_{33} + M_4F_{43}]$

Note: See Table 4.4 for values of F_{ij}

11. $E_{LV\cdot G} = 0.0110\ (R_{LV\cdot G})(S_{LV\cdot G})$ = emissions-line 195
12. $E_{HV\cdot G} = 0.0110\ (R_{HV\cdot G})(S_{HV\cdot G})$ = emissions-line 196
13. $E_{HV\cdot D} = 0.0110\ (R_{HV\cdot D})(S_{HV\cdot D})$ = emissions-line 200
14. $\mathrm{Var}\ (M_{LV\cdot G}) = (M_{LV\cdot G})^2 \left[P^2_{13.6} + P_{G_1}^2\right]$

    Note: $P_{13.6} = 0.032$
15. $\mathrm{Var}\ (M_{HV\cdot G}) = (M_{HV\cdot G})^2 \left[P^2_{8.4} + P^2_{G_2}\right]$

    Note: $P_{8.4} = 0.032$
16. $\mathrm{Var}\ (M_{HV\cdot D}) = (M_{HV\cdot D})^2 \left[P^2_{5.0} + P^2_{G_3}\right]$

    Note: $P_{5.0} = 0.032$
17. $\mathrm{Var}\ (M_T) = \mathrm{Var}\ (M_{LV\cdot G}) + \mathrm{Var}\ (M_{HV\cdot G}) + \mathrm{Var}\ (M_{HV\cdot D})$

Table 4.4 EMISSION FACTORS FOR MOTOR VEHICLES

Road type	Light gasoline	Vehicle type heavy gasoline	Heavy diesel
Limited access	F_{11}	F_{12}	F_{13}
Rural	F_{21}	F_{22}	F_{23}
Suburban	F_{31}	F_{32}	F_{33}
Urban	F_{41}	F_{42}	F_{43}

	Part.	SO_x	NO_x	HC	CO
F_{11}	0.300	0.180	4.300	7.800	34.000
F_{21}	0.300	0.180	4.300	8.000	37.000
F_{31}	0.300	0.180	4.300	8.800	45.000
F_{41}	0.300	0.180	4.300	10.000	59.000
F_{12}	0.300	0.180	10.000	16.000	58.000
F_{22}	0.300	0.180	10.000	17.000	63.000
F_{32}	0.300	0.180	10.000	19.000	76.000
F_{42}	0.300	0.180	10.000	23.000	100.000
F_{13}	1.200	2.400	34.000	3.400	20.000
F_{23}	1.200	2.400	34.000	3.400	20.000
F_{33}	1.200	2.400	34.000	3.400	20.000
F_{43}	1.200	2.400	34.000	3.400	20.000

18. $\mathrm{Var}\ (R_{LV\cdot G}) = (R_{LV\cdot G})^2 \left[\frac{\mathrm{Var}\ (M_{LV\cdot G})}{(M_{LV\cdot G})^2} + \frac{\mathrm{Var}\ (M_T)}{(M_T)^2}\right]$

19. $\mathrm{Var}\ (R_{HV\cdot G}) = (R_{HV\cdot G})^2 \left[\frac{\mathrm{Var}\ (M_{HV\cdot G})}{(M_{HV\cdot G})^2} + \frac{\mathrm{Var}\ (M_T)}{(M_T)^2}\right]$

20. $\mathrm{Var}\ (R_{HV\cdot D}) = (R_{HV\cdot D})^2 \left[\frac{\mathrm{Var}\ (M_{HV\cdot D})}{(M_{HV\cdot D})^2} + \frac{\mathrm{Var}\ (M_T)}{(M_T)^2}\right]$

21. $\mathrm{Var}\ (M_1F_{11}) = (M_1F_{11})^2 \left[(P_{M_1})^2 + (P_{11})^2\right]$

Note: See Table 4.5 for values of P_{ij}

22. $\mathrm{Var}\ (M_2F_{21}) = (M_2F_{21})^2 \left[(P_{M_2})^2 + (P_{21})^2\right]$

23. $\mathrm{Var}\ (M_3F_{31}) = (M_3F_{31})^2 \left[(P_{M_3})^2 + (P_{31})^2\right]$

24. $\mathrm{Var}\ (M_4F_{41}) = (M_4F_{41})^2 \left[(P_{M_4})^2 + (P_{41})^2\right]$

25. $\mathrm{Var}\ (\mathrm{SUMLVG}) = \mathrm{Var}\ (M_1F_{11}) + \mathrm{Var}\ (M_2F_{21}) + \mathrm{Var}\ (M_3F_{31})$
$+ \mathrm{Var}\ (M_4F_{41})$

26. $\mathrm{Var}\ (E_{LV\cdot G}) = (E_{LV\cdot G})^2 \left[\frac{\mathrm{Var}\ (R_{LV\cdot G})}{(R_{LV\cdot G})^2} + \frac{\mathrm{Var}\ (\mathrm{SUMLVG})}{(S_{LV\cdot G})^2}\right]$

27. $\mathrm{Var}\ (E_{LV\cdot G})$ = Variance of emissions-line 195

28. $\mathrm{Var}\ (M_1F_{12}) = (M_1F_{12})^2 \left[(P_{M_1})^2 + (P_{12})^2\right]$

29. $\mathrm{Var}\ (M_2F_{22}) = (M_2F_{22})^2 \left[(P_{M_2})^2 + (P_{22})^2\right]$

30. $\mathrm{Var}\ (M_3F_{32}) = (M_3F_{32})^2 \left[(P_{M_3})^2 + (P_{32})^2\right]$

Table 4.5 PRECISION OF EMISSION FACTORS FOR MOTOR VEHICLES

	Part.	SO_x	NO_x	HC	CO
P_{11}	0.211	0.146	0.028	0.023	0.036
P_{21}	0.211	0.146	0.028	0.024	0.036
P_{31}	0.211	0.146	0.028	0.024	0.036
P_{41}	0.211	0.146	0.028	0.025	0.036
P_{12}	0.211	0.146	0.028	0.018	0.035
P_{22}	0.211	0.146	0.028	0.018	0.035
P_{32}	0.211	0.146	0.028	0.019	0.034
P_{42}	0.211	0.146	0.028	0.019	0.034
P_{13}	0.211	0.146	0.035	0.237	0.357
P_{23}	0.211	0.146	0.035	0.237	0.357
P_{33}	0.211	0.146	0.035	0.237	0.357
P_{43}	0.211	0.146	0.035	0.237	0.357

31. $\text{Var}\ (M_4F_{42}) = (M_4F_{42})^2 \left[(P_{M_4})^2 + (P_{42})^2 \right]$

32. $\text{Var (SUMHVG)} = \text{Var}\ (M_1F_{12}) + \text{Var}\ (M_2F_{22}) + \text{Var}\ (M_3F_{32})$
$+ \text{Var}\ (M_4F_{42})$

33. $\text{Var}\ (E_{HV\cdot G}) = (E_{HV\cdot G})^2 \left[\frac{\text{Var}\ (R_{HV\cdot G})}{(R_{HV\cdot G})^2} + \frac{\text{Var (SUMHVG)}}{(S_{HV\cdot G})^2} \right]$

34. $\text{Var}\ (E_{HV\cdot G})$ = Variance of emissions-line 196

35. $\text{Var}\ (M_1F_{13}) = (M_1F_{13})^2 \left[(P_{M_1})^2 + (P_{13})^2 \right]$

36. $\text{Var}\ (M_2F_{23}) = (M_2F_{23})^2 \left[(P_{M_2})^2 + (P_{23})^2 \right]$

37. $\text{Var}\ (M_3F_{33}) = (M_3F_{33})^2 \left[(P_{M_3})^2 + (P_{33})^2 \right]$

38. $\text{Var}\ (M_4F_{43}) = (M_4F_{43})^2 \left[(P_{M_4})^2 + (P_{43})^2 \right]$

39. $\text{Var (SUMHVD)} = \text{Var}\ (M_1F_{13}) + \text{Var}\ (M_2F_{23}) + \text{Var}\ (M_3F_{33})$
$+ \text{Var}\ (M_4F_{43})$

40. $\text{Var}\ (E_{HV\cdot D}) = (E_{HV\cdot D})^2 \left[\frac{\text{Var}\ (R_{HV\cdot D})}{(R_{HV\cdot D})^2} + \frac{\text{Var (SUMHVD)}}{(S_{HV\cdot D})^2} \right]$

41. $\text{Var}\ (E_{HV\cdot D})$ = Variance of emissions-line 200

42. Go on to next area source category

If M_1, M_2, M_3, M_4 are all blank, an alternate method is used to calculate emissions and variance of emissions.

4. $P_U = 0.1$ (density code-position 236)

5. $P_R = 1.0-P_U$

6. $A_{LV\cdot G} = [P_RF_{21} + P_UF_{41}]$

7. $A_{HV\cdot G} = [P_RF_{22} + P_UF_{42}]$

8. $A_{HV\cdot D} = [P_RF_{23} + P_UF_{43}]$

9. $E_{LV\cdot G} = \dfrac{(M_{LV\cdot G})(A_{LV\cdot G})}{(9.072 \times 10^5)}$ = emissions-line 195

10. $E_{HV\cdot G} = \dfrac{(H_{HV\cdot G})(A_{HV\cdot G})}{(9.072 \times 10^5)}$ = emissions-line 196

11. $E_{HV\cdot D} = \dfrac{(M_{HV\cdot D})(A_{HV\cdot D})}{(9.072 \times 10^5)}$ = emissions-line 200

12. $\text{Var}\ (M_{LV\cdot G}) = (M_{LV\cdot G})^2 \left[P_{13.6}^2 + P_{G_1}^{\ 2} \right]$

13. $\text{Var}\ (M_{HV\cdot G}) = (M_{HV\cdot G})^2 \left[P_{8.4}^2 + P_{G_2}^2 \right]$

14. $\text{Var}\ (M_{HV\cdot D}) = (M_{HV\cdot D})^2 \left[P_{5.0}^2 + P_{G_3}^2 \right]$

15. $\text{Var}\ (P_R F_{21}) = (P_R F_{21})^2 \left[\dfrac{\text{Var}\ (P_R)}{(P_R)^2} + P_{21}^2 \right]$

16. $\text{Var}\ (P_U F_{41}) = (P_U F_{41})^2 \left[\dfrac{\text{Var}\ (P_U)}{(P_U)^2} + P_{41}^2 \right]$

17. $\text{Var}\ (A_{LV\cdot G}) = \text{Var}\ (P_R F_{21}) + \text{Var}\ (P_U F_{41})$

18. $\text{Var}\ (E_{LV\cdot G}) = (E_{LV\cdot G})^2 \left[\dfrac{\text{Var}\ (M_{LV\cdot G})}{(M_{LV\cdot G})^2} + \dfrac{\text{Var}\ (A_{LV\cdot G})}{(A_{LV\cdot G})^2} \right]$

19. $\text{Var}\ (E_{LV\cdot G})$ = Variance of emissions-line 195

20. $\text{Var}\ (P_R F_{22}) = (P_R F_{22})^2 \left[\dfrac{\text{Var}\ (P_R)}{(P_R)^2} + P_{22}^{\ 2} \right]$

21. $\text{Var}\ (P_U F_{42}) = (P_U F_{42})^2 \left[\dfrac{\text{Var}\ (P_U)}{(P_U)^2} + P_{42}^{\ 2} \right]$

Note: $\text{Var}\ (P_U) = \text{Var}\ (P_R) = 0$

22. $\text{Var}\ (A_{HV\cdot G}) = \text{Var}\ (P_R F_{22}) + \text{Var}\ (P_U F_{42})$

23. $\text{Var}\ (E_{HV \cdot G}) = (E_{HV \cdot G})^2 \left[\frac{\text{Var}\ (M_{HV \cdot G})}{(M_{HV \cdot G})^2} + \frac{\text{Var}\ (A_{HV \cdot G})}{(A_{HV \cdot G})^2} \right]$

24. $\text{Var}\ (E_{HV \cdot G})$ = Variance of emissions-line 196

25. $\text{Var}\ (P_R F_{23}) = (P_R F_{23})^2 \left[\frac{\text{Var}\ (P_R)}{(P_R)^2} + P_{23}{}^2 \right]$

26. $\text{Var}\ (P_U F_{43}) = (P_U F_{43})^2 \left[\frac{\text{Var}\ (P_U)}{(P_U)^2} + P_{43}{}^2 \right]$

27. $\text{Var}\ (A_{HV \cdot D}) = \text{Var}\ (P_R F_{23}) + \text{Var}\ (P_U F_{43})$

28. $\text{Var}\ (E_{HV \cdot D}) = (E_{HV \cdot D})^2 \left[\frac{\text{Var}\ (M_{HV \cdot D})}{(M_{HV \cdot D})^2} + \frac{\text{Var}\ (A_{HV \cdot D})}{(A_{HV \cdot D})^2} \right]$

29. $\text{Var}\ (E_{HV \cdot D})$ = Variance of emissions-line 200

30. Go on to next area source.

4.4.2 Procedure B

Procedure for forest fires, slash burning, frost control and coal refuse burning

$E = TQF$ tons per year

where T = thruput (see below)

Q = quantity (see below)

F = emission factor (See Table 4.1)

$\text{Var}\ (E) = E^2\ [P_T{}^2 + P_Q{}^2 + P_F{}^2]$

where P_T = precision of thruput (see below)

P_Q = precision of quantity

P_F = precision of emission factor (Table 4.3)

	T	Q	P_T	P_Q
Forest Fires	326-332	333-335	0.050	0.15
Slash Burning	336-341	342-344	50/T	0.25
Frost Control	345-348	349-351	0.5/T	5/Q
Coal Refuse Burning	356-361	362-364	0.270	0

If T, Q, or F are blank do not calculate E or Var (E) and print appropriate error message.

4.4.3 Procedure C

For off highway gasoline vehicle it is necessary to calculate the precision of thruput (P_T) for the specific county as follows:

$$P_T = \frac{\left[0.022T^2 - 0.572TP + 28.73P^2\right]^{1/2}}{T}$$

where:

T = thruput (position 214-218)

P = population (position 232-235)

4.5 PROCEDURE FOR CALCULATING POINT SOURCE DATA

A point source record has a P in position 9 of the NEDS user file record. A point source is uniquely identified by the following:

Position	Format abbr.	Format defin.	Name
10-11	ST NO	99	State Code
12-15	COUNTY	9999	County Code
16-18	'999'	XXX	9's filler
19-22	PLANT ID	9999	plant identification number
23-24	PT	99	point identification number
25-32	SCC CODE	99999999	source classification number

For some point sources emissions are assigned to more than one SCC code. In this situation the file contains a record for each SCC code, and the records are in sequence by code number.

The point source emission value is read from the file. Locations of the emission data for each pollutant are as follows:

Position	Format abbr.	Format def.	Name
433-442	PARTICULATE EMISSIONS	9(7)V999	particulate emissions (tons/year)
443-452	SO_2 EMISSIONS	9(7)V999	SO_2 emissions (tons/year)
453-462	NO_x EMISSIONS	9(7)V999	NO_x emissions (tons/year)
463-472	HC EMISSIONS	9(7)V999	HC emissions (tons/year)
473-482	CO EMISSIONS	9(7)V999	CO emissions (tons/year)

The program incorporates three options depending on the value of emission (E) for a point source.

4.5.1 If E > 0

(1) Add emission value (E) to the appropriate point source category designated by the SCC code as shown in Figure 4.4. For example, Electric Generation-Anthracite SCC = 1 01 001 XX and includes the following individual SCC's.

1 01 001 01

1 01 001 02

1 01 001 03

1 01 001 04

1 01 001 05

1 01 001 06

1 01 001 99

Note: The SCC code for Industrial Process (Point) - Evaporation (line 139 of the output listing) is given as 3 08 on Figure 4.4. In the NEDS User File SCC codes for these sources are between 4 01 001 01 and 4 90 999 99. To facilitate calculation of hierarchial totals required for the emission inventory, these SCC codes are transposed to a dummy code of 3 08 XXX XX.

(2) Calculate the variance Var (E) of the emission value as follows:

$$\text{Var (E)} = E^2 \left[P_T^{\ 2} + P_F^{\ 2} + P_C^{\ 2} + P_D^{\ 2} \right]$$

where E = emissions in tons/year

P_T = precision of thruput

P_F = precision of emission factor

P_C = precision of ash (A) or sulfur (S) content

P_D = precision of penetration (control device efficiency)

Precisions of thruput values are presented in Table 2.17.

In the event that one (or more) of the required precisions cannot be determined, the value of Var (E) is set to zero for the point source. An error message is then printed indicating that the appropriate precision term(s) is missing.

Precisions of emission factors are presented in Tables G-1 through G-5 of Appendix G for the five pollutants. The numbers of entries in these tables are 613 for particulate, 293 for sulfur dioxide, 271 for nitrogen oxide, 349 for hydrocarbon, and 259 for carbon monoxide. The SCC code (position 25-32 in record) and the method of estimation (position 243-247 in record depending upon pollutant) are needed to determine precision. Acceptable methods of determining precision are coded 1, 2, 3, 4 and 5. If the method code is blank use the precision of the emission factor for Method 4. If the method code is zero do not compute a value for Var (E) but read the next record.

Tables G-1 through G-5 contain estimates of precision for the emission factor for the SCC's included in (give the name of publication or date of list), If this list is expanded it is necessary to update the corresponding tables in the computer program. Procedures for such an update are included in the system operating procedures. In the event that a point source in the NEDS User File has an SCC which is not included in Tables G-1 through G-2, the system will substitute a value of zero for P_f (precision of the emission factor) and print an error message indicating that the emission factor is not in the appropriate table.

4.5.1.1 Precision of Values for Ash (or sulfur) content -

As mentioned earlier the emission factor for some SCC's includes a suffix of A or S. In such cases the precision of A or S (P_C) is included in the calculation of the Var (E).

If the pollutant is particulates and the SCC is

1 XX 001 XX
1 XX 002 XX
1 XX 003 XX
3 90 001 XX
3 90 002 XX
3 90 003 XX

$$P_C = \frac{N}{A}$$

If $A \leq 12.0$ $N = 0.5$
$A > 12.0$ $N = 1.0$
If $A = 0$ $P_C = 0$
A = blank read standard value of A for this SCC from Table H-1 of Appendix H.

If the pollutant is sulfur dioxide and the SCC is

1 XX 001 XX
1 XX 002 XX
1 XX 003 XX
3 90 001 XX
3 90 002 XX
3 90 003 XX

$$P_C = \frac{M}{S}$$

where $M = 0.1$ If $S \leq 2.00$

$M = 0.2$ If $S > 2.00$

If the pollutant is sulfur dioxide and the SCC is

1 XX 004 XX

1 XX 005 XX

3 90 004 XX

3 90 005 XX

$$P_C = \frac{M}{S}$$

where $M = 0.03$ If $S \leq 0.50$

$M = 0.04$ $0.50 < S \leq 1.00$

$M = 0.05$ $1.00 < S \leq 2.00$

$M = 0.07$ $2.00 < S \leq 3.00$

$M = 0.09$ $3.00 < S \leq 4.00$

$M = 0.12$ $4.00 < S \leq 5.00$

$M = 0.14$ $S > 5.00$

If the pollutant is sulfur dioxide and the SCC is

1 XX 010 XX

$$P_C = \frac{M}{S}$$

where $M = 0.0001$ all S

If $S = 0$ $P_C = 0$

S = blank read standard value of S for this SCC from Table H-1 of Appendix H.

SIEFA is capable of calculating the precision of either ash or sulfur content only for the SCC's listed above. In order to expand this list of acceptable SCC's it is necessary to develop the appropriate algorithm for calculating precisions. The algorithm must then be programmed into the system. Instructions for updating SIEFA for new algorithms are included in the system operating procedures.

4.5.1.2 Precision of Penetration Values - The precision of values for penetration (i.e., the number 1 minus the control device efficiency (%) are presented in Table 4.6.

If the control device efficiency is:

>0 see Table 4.6

=0 $P_D = 0$

= blank see Table H-1 for standard control device efficiency for the SCC

4.5.2 If E = 0 and Estimated Emission is Zero

If E = 0 and estimated emission for the pollutant is zero (see below for position in record) read next record.

Position	Format Abbr.	Format Def.	Name
208-214	EMIS EST-PAR	9999999	estimated emissions - particulates (tons/year)
215-221	EMIS EST-SO_2	9999999	estimated emissions - SO_2 (tons/year)
222-228	EMIS EST-NO_x	9999999	estimated emissions - NO_x (tons/year)
229-235	EMIS EST-HC	9999999	estimated emissions - CO (tons/year)

Table 4.6 PRECISION OF PENETRATION

P = (100 - Def.)

Def = Efficiency of Control Device:

Read positions	178-180 - Part
	181-183 - SO_2
	184-186 - NO_x
	187-189 - HC
	190-192 - CO

Var (P) = From Table Below

$$P_D = \frac{\text{Var (P)}}{(P)^2}$$

Position in Record = XXX

Identification Code = 321

If (1) $\neq$ 0 and $\neq$ 5 then Var(P) = 0.01

If (1) = 5 then Var(P) = 0.09

If (1) = 0 and (2) $\neq$ 0 and (2) $\neq$ 5 then Var(P) = 0.25

If (1) = 0 and (2) = 5 and (3) < 8 then Var(P) = 25.0

If (1) = 0 and (2) = 5 and (3) $\geq$ 8 then Var(P) = 6.25

If (1) = 0 and (2) = 0 then Var(P) = 25.0

4.5.3 If E = 0 and Estimated Emission is Blank

C. If E = 0 and estimated emissions for the pollutant is blank, an approximate emission for the source is calculated by the following equation:

$$E = \frac{TFD}{2000} \text{ tons per year}$$

where T = operating rate (thruput) in positions 314-320

F = emission factor for SCC and pollutant. (SCC table should be available in NEDS program.)

D = 1 minus estimated control efficiency (penetration).

The positions (in the record) of estimated control efficiency values are given below.

Position	Format abbr.	Format def.	Name
178-180	ECE-PAR	99V9	estimated control efficiency particulates (%)
181-183	ECE-SO_2	99V9	estimated control efficiency SO_2 (%)
184-186	ECE-NO_x	99V9	estimated control efficiency NO_x (%)
187-189	ECE-HC	99V9	estimated control efficiency HC (%)
190-192	ECE-CO	99V9	estimated control efficiency CO (%)

Note; The emission factors for the following SCC's have suffixes of A or S;

SCC	**Suffix**	
1 XX 001 XX	A	S
1 XX 002 XX	A	S
1 XX 003 XX	A	S
1 XX 004 XX		S
1 XX 005 XX		S
3 90 001 XX	A	S
3 90 002 XX	A	S
3 90 003 XX	A	S
3 90 004 XX		S
3 90 005 XX		S

The positions of S and A in the record are

Position	Format abbr.	Format def.	Name
328-330	SUL CONT	99V9	% sulfur content
331-333	ASH CONT	99V9	% ash content

If T, D, A, or S is blank in the record read standard value for the SCC from Table H-1 of Appendix H.

If there is no emission factor for this SCC read the next record.

Having calculated an approximate emission for the point source,

1. Add the approximate emissions for this source to the total approximate emissions for the point source category.
2. Add 1 to the count of the number of sources for which approximate emissions were calculated for the point source category.

3. **Prepare a list of each point source for which an approximate emission was calculated including:**

   State code
   County code
   Plant identification No.
   Point identification No.
   SCC
   Operating rate
   Ash (or sulfur) content
   Control device efficiency

   Note: Flag each parameter for which an approximated value is used.

When the last point source for a county has been processed, determine from the users request whether an output tabulation is to be prepared for this single county. If no output is required at this point, read and process data for area and point source records of the next county. If an output is required, calculate the hierarchical totals or other values specified on the output format.

4.6 PREPARATION OF OUTPUT

A. Calculate sum of estimated and approximated emissions for each source category specified in the output format (Table 4.1). Note that because no approximate emissions are calculated for area sources, the value for estimated and approximated emissions will be equal to the value for estimated emissions.

B. Calculate the hierarchical totals for estimated emissions, variance of estimated emissions, number of sources for which emissions are approximated, and estimated and approximated emissions.

C. Calculate standard deviation of estimated emissions for each appropriate entry on the output format as follows:

$$\text{Standard deviation} = [\text{Variance}]^{1/2}$$

D. Print output listing.

E. Continue to process other geographical areas or other pollutants as specified by user's request card.

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